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STUDIES ON MACKEREL: FAT VARIATIONS—AND CERTAIN BIOLOGICAL ASPECTS*

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1. Introduction

The Indian Mackerel (*Rastrelliger kanagurta* Ruppel) is one of the most economically important fishes on the West Coast of India from Ratnagiri in the North to Cochin in the South. During the last two decades since the decline of the oil sardine fishery in the early thirties, the mackerel fisheries have been the mainstay of Malabar and South Kanara. From the statistics of landing of the mackerel collected by the Madras Fisheries from 1925–26 onwards, it is seen that the catches varied from 15,000 maunds in 1930–31 to 84,26,860 maunds in 1931–32. The average landings for the five-year period between 1944–45 and 1948–49 was 18,48,580 maunds. This fish ranked first in quantity on the coast from 1938–39 onwards. In view of its importance, the mackerel has been engaging the attention of fishery workers here for sometime and with the establishment of the Fisheries Technological Station, it was proposed to work on the biochemical variations of this fish in relation to the biological changes taking place in the successive fishing seasons. With this end in view an attempt was made to find out the relationship and the causative factors involved in the biological and bio-chemical variations.

Amongst the seasonal variations in the composition of fish, *i.e.*, fat, water and protein, the greatest variables have been fat and water (Riegol, 1948). In the Indian mackerel fat or oil content has been found to be the chief variable (Venkataraman and Chari, 1951) as observed by Atwater (1892), Milroy (1908), Johnstone (1915), Bruce (1924), El. Saby (1937), Wilson (1939), and Stansby and Lemon (1941), in different fishes in other parts of the world. Reciprocal relationship between fat and water and seasonal changes have been observed in the mackerel. It has been suggested that this variation may be due to certain biological factors (Venkataraman and Chari, 1951). This paper deals with the relationship of variation in fat

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to seasonal appearance of the different sizes of mackerel, the availability of their food, the intensity of their feeding and their spawning conditions.

2. MATERIALS AND METHODS

The methods of sampling and chemical analysis employed for fat variation of either flesh or whole fish are those published in a previous communication (Venkataraman and Chari, 1951).

The length of the fish was measured from the tip of the snout to the tip of the longest caudal ray. The sexual condition and the stages of maturity were determined according to Hjort's scale (*Publications de circonstance*, No. 53).

3. SIZE GROUP APPEARANCE

(*a*) The season of appearance of the various size groups of mackerel can be divided broadly into three periods, *viz.*,

1. July to September,
2. October to January and
3. February to the end of the season—this period extends sometimes right up to the beginning of the South-West Monsoon when the fish disappear from the fishery.

The smallest size of mackerel caught was 4 cm. (*Madras Fisheries Administration Report*—1940) and the species is known to reach a maximum size of more than 25 cm. (Devanesen and John, 1940; Chidambaram and Venkataraman, 1946).

A progressive decrease in the range of sizes obtainable is seen in the appearance of mackerel from August, when fish of all sizes occur to the closing period of the season by about February, when only larger sizes are present. The smaller and intermediate-sized individuals disappear from the fishery gradually until in February we find only the larger sizes in the fishery. These larger sizes constitute the fishery from this month onwards to the end of the season.

(*b*) The appearance of the different sizes in the three years 1947–48, 1948–49 and during 1949–50 in the three periods are described below:

1947–50 *First Period, July to September:* 1947:—In the first period fish ranging in size from 9·5 to 21·5 cm. were present. Fish larger than 19 cm. were more abundant than smaller ones. In July 1947 the sizes caught ranged from 9·5 cm. to 19·5 cm. The size range of fish occurring in August was very narrow, *viz.*, between 12·5 and 15·0 cm.; the smaller sized ones and bigger sized ones being absent from the catches. The larger sizes of

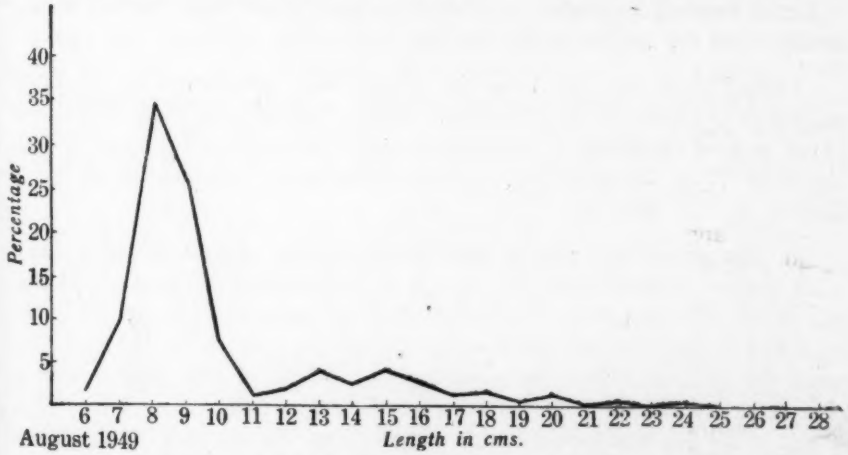
more than 18 or 19 cm. made their appearance again in September but the smaller sizes had disappeared from the fishery in August itself.

1948:—In July the sizes were between 11·5 and 13·5 cm. The bigger sizes of fish made their appearance in August when fish between 12·8 cm. to 24·5 cm. constituted the fishery. The fish appearing in September measured between 17 and 24·5 cm. in length. The intermediate sizes between 14 and 19 cm. dwindled from the fishery during this month.

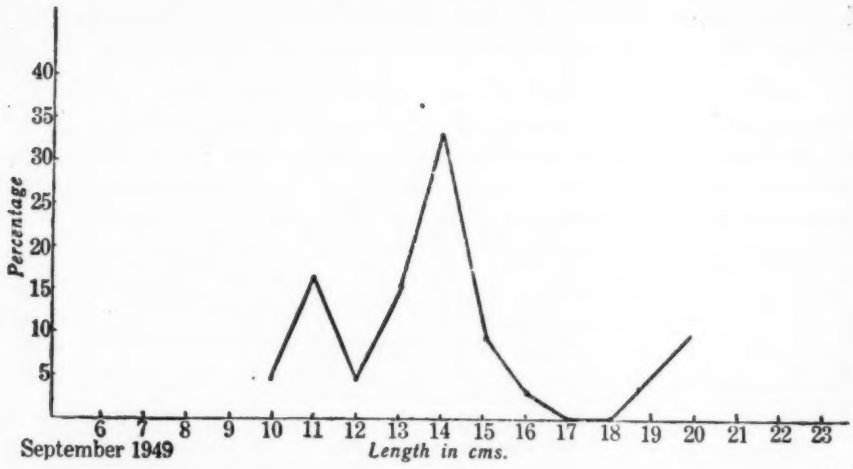
1949:—The small quantity of mackerel landed in July along with other fishes ranged in size from 13·5 to 15·2 cm. Fish of all sizes between 6·1 and 23·7 cm. were caught in August, and only in that month did fish measuring about 6 cm. occur. The same size groups persisted in September also. But the smallest sizes were going out of the fishery by then (*vide* Graphs 1 and 2).

The range of size of fish caught in 1948 was slightly greater than in 1947 but the fish were not so small as those caught in 1947. The bigger sizes above 19 cm. were not as numerous as in 1947 though these were the most abundant in the first period of 1948 also. In 1949 fish 6 cm. in length were occurring in plenty and the sizes smaller than 14 cm. completely dominated the catches, those above 19 cm. being the least abundant.

Second Period: *October-January* 1947–48.—In this period of the 1947–48 season no fish of size below 18 cm. occurred in the catches at all. The range of size in this year was very narrow being between 18 cm. and 24 cm. From October onwards these big fish constituted the entire fishery. In October



GRAFH 1. Percentage-size composition of catches of mackerel for August 1949



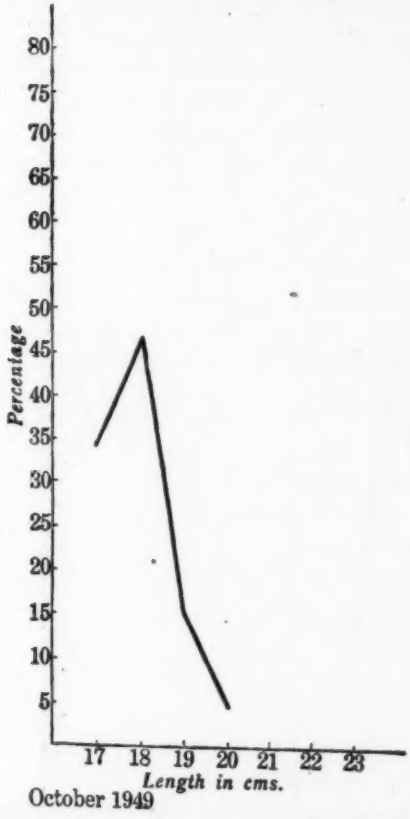
GRAPH 2. Percentage-size composition of catches of mackerel for September 1949

the sizes of fish were between 18 and 20 cm. But from November onwards larger ones measuring upto 24 cm. were found in the catches. In January fish measuring between 19 and 23·5 cm. only occurred.

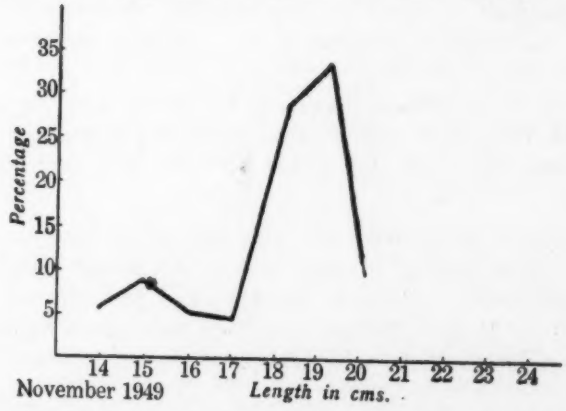
1948–49.—In this year also October showed a narrow range of size of fish measuring between 19 and 21·5 cm. In November smaller fish measuring about 15 cm. entered the fishery along with the bigger fish measuring 22·5 cm. In December the fishery constituted of fish of sizes above 20 cm. Again in January somewhat smaller fish about 18 cm. were present in the fishery. But the maximum size for this month did not exceed 20·8 cm.

1949–50.—In October 1949 the fishery was represented by mackerel ranging in size from 16·9 to 19·9 cm. Fish of still smaller sizes but above 14 cm. entered the fishery in November; and in December the range of size was from 17 to 18·9 cm. and in January between 19·2 and 20 cm. (*vide* Graphs, 3, 4, 5 and 6).

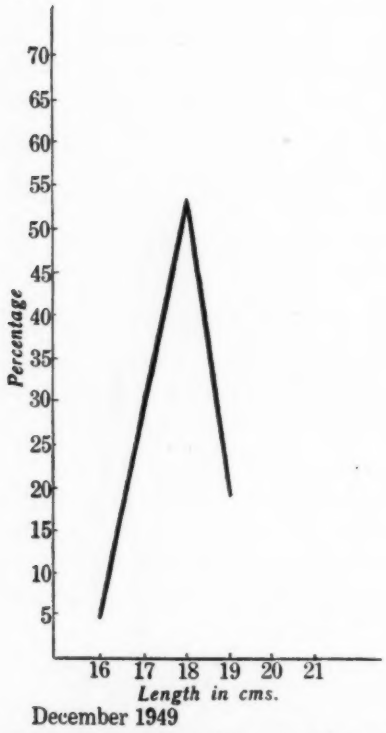
In this period fish smaller than 14 cm. did not appear in the fishery at all as observed in all three years. But in 1947–48 even fish between 14 cm. and 18 cm. did not occur. In 1948–49 fish of a smaller size occurred forming a minor proportion of the fishery. The bigger sizes above 19 cm. dominated the catches. The fish occurring in 1949–50 in this second period were generally smaller than in either of the other two years. The range of size of the fish was between 14·3 and 20·5 cm. In the year 1947–48 the bigger fish were more numerous than in 1948–49 and 1949–50. The whole



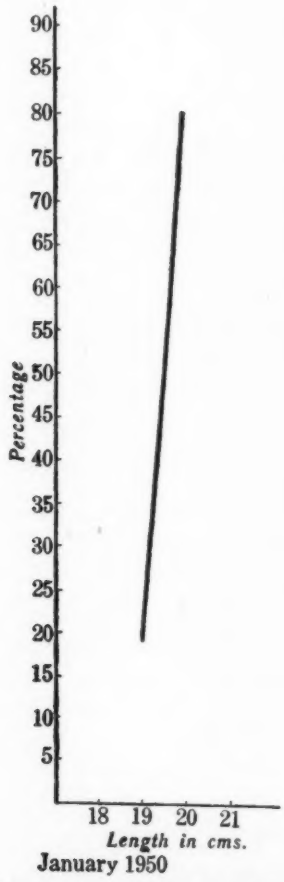
GRAPH 3. Percentage-size composition of catches of mackerel for October 1949



GRAPH 4. Percentage-size composition of catches of mackerel for November 1949



GRAPH 5. Percentage-size composition of catches of mackerel for December 1949



GRAPH 6. Percentage-size composition of catches of mackerel for January 1950

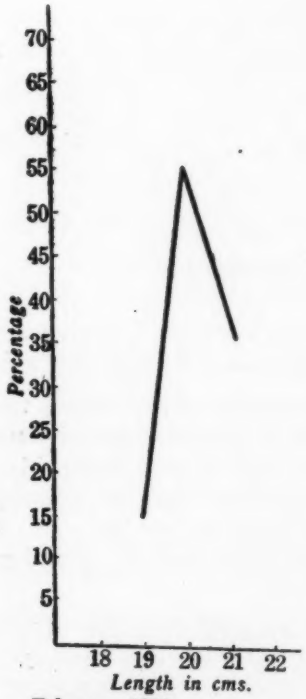
of this period in 1947–48 was dominated by fish of a bigger size than what was usual for this period. Smaller sizes were completely absent. In 1948–49 the sizes were typical of this period but still they were bigger than in 1949–50.

Third Period—From February to the end of the season when mackerel disappears.—1948: Fish of a bigger size at this period ranging from 20·5 to 24 cm. occurred in February. In April and May the fish were of the size from 21 to 24 cm. In June only large fish measuring from 22·6 to 24·6 cm. were represented in the fishery.

1949.—In February fish ranging in size from 20·7 to 22·5 cm. were represented in the catch, but smaller fish measuring 18 cm. appeared rather unusually. During the rest of the period only the big size varying in length from 20 to 24 cm. occurred in the fishery.

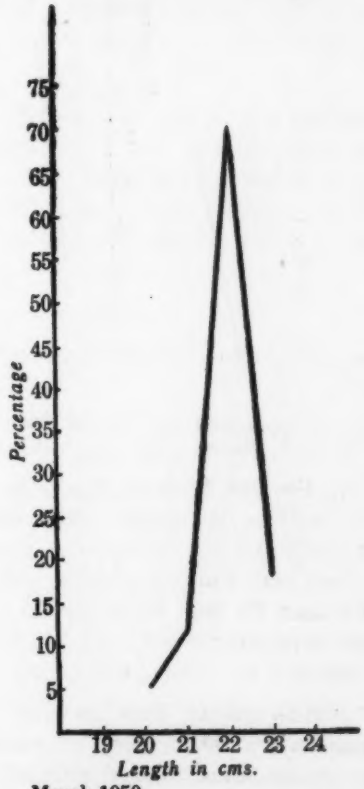
1950.—Conforming to the usual trend of appearance, in this year there were only fish between 19 and 23 cm. There were never the maximum sizes, not even those as big as in the two previous years. From February to March the size ranges were the same; only in April did the largest sizes measuring about 23 cm. enter the fishery (*vide* Graphs 7, 8 and 9).

In this period the size groups occurring were the same. Only the large sizes measuring above 19 cm. occurred. It may however be noticed that the larger sizes among these are found towards the end of the season.



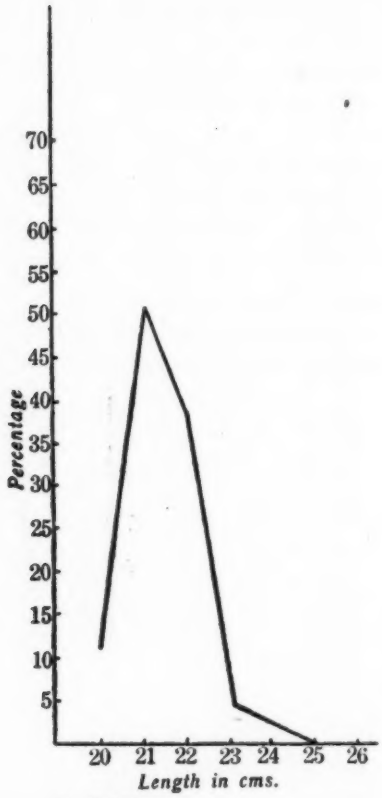
February 1950

GRAPH 7. Percentage-size composition of catches of mackerel for February 1950



March 1950

GRAPH 8. Percentage-size composition of catches of mackerel for March 1950



April 1950

GRAPH 9. Percentage-size composition of catches of mackerels for April 1950

In the first of these three periods different sizes of fish ranging from 6 cm. to 25 cm. are caught. With the beginning of the second period certain size groups are not represented in the fishery. Fish of sizes below 14 cm. are not found in the fishery for the rest of the season. Another noticeable fact is that the very large sizes in this period occur but are very rare. In the third period the fish of sizes upto 10 cm. are absent, and only larger sizes of mackerel are represented in the catches.

Size Groups in 1949–50.—The details of appearance in the different seasons of the various sizes of mackerel occurring in the year 1949–50 are given below (see appended Graphs).

Very young mackerel were met with in the months of July and August 1949. In July the fish were mostly between 13 and 16 cm. Catches were

scarce in that month. In August fish of sizes from 6 cm. to 12 cm. occurred in large numbers. The bulk of August catches consisted of fish between 6 cm. and 15 cm. even though they included fish of size up to 24·5 cm. These large sizes, however, disappeared quite early in the month from the fishery. There were stray ones above 15 cm. in the latter half of the month. In September again there is a similar trend with fish bigger than 15 cm. occurring in the beginning of the month. These disappeared from the fishery in the first week. In the rest of the month fish between 10 cm. and 15 cm. dominated the catches.

The fishery in October comprised of fish of sizes ranging between 16 and 19 cm. Though the dominant sizes lay between 16 and 19 cm. in the month of November there was an admixture of smaller sizes of fish measuring between 14 and 16 cm. In the month of December also the same group constituted the entire fishery. And there were no fish above 20 cm. in length in that month at all.

From January onwards there is no admixture of smaller size groups. In January the fishery comprised of fish above 20 cm. In February the range of size was between 19 and 21 cm. only. In March the fishery consisted of fish, the majority of which measured more than 20 cm. In the month of April the same size dominated the catch with the fish above 22 cm. forming a small proportion.

The following are evident from the above data:—

(i) The presence generally of all size groups of mackerel in the months of July, August and September.

(ii) The fishery comprising mostly of fish of intermediate size in the months between October and January.

(iii) The occurrence of fish of only the larger sizes above 19 cm. after January, in the season.

The following two observations in this sequence of appearances and disappearances are of importance in the study of the movements of mackerel.

(i) The disappearance of fish smaller than 14 cm. by October (or November at the latest) from the fishery, and

(ii) The disappearance of mackerel below 19 cm. from the fishery in January.

To sum up, the mackerel fishery of the West Coast, mainly confined to the intense fishing in the months of October, November, December, January and February, consists of fish of an intermediate size which are

still sexually immature. The fish occur in the coastal waters from July or August onwards but the catches are not comparable to the catches of the abovenamed months in which intense fishing is carried on. In this early period fish of all sizes occur, yielding to the intense fishery of the months between October and February when intermediate sizes only occur, whereafter the limited fishery is supported purely by mackerel of large sizes.

(*c*) *The feeding activity of mackerel*

The mackerel is mainly a plankton feeder. Its food includes species of *Coscinodiscus*, *Thalassiothrix*, *Nitzschia*, *Asterionella*, *Pleurosigma*, *Rhizosolenia*, *Biddulphia*, *Planktoniella*, *Chætoceras*, *Dytilum*, Dinoflagellates, *Copepods*, *Evadne*, *Leucifer*, *Daphnids*, Larval Crustaceans, Larval bi-valves, *Limacina*, *Pteropods*, Bristle-worm, etc. (see for fuller account of food of mackerel; Hornell, 1910; Devanesen and John, 1940; Chidambaram, 1944; Chidambaram and Venkataraman, 1946).

The intensity of feeding of mackerel of different size groups as indicated by the volume of the stomach contents is given below: This analysis refers generally to the latter part of 1949 and the beginning of 1950.

TABLE I

Average Volume of feed of mackerel in the different months in c.c.

No.	Size group	Jan.	Feb.	Mar.	April	May	Aug.	Sept.	Oct.	Nov.	December
1	17 cm.								1·00	0·90	0·76
2	18 cm.								0·50	1·61	1·33
3	19 cm	0·40	0·47	1·00					1·00	1·47	0·73
4	20 cm.	0·53	1·01	0·82	1·33					1·34	2·1 ('48)
5	21 cm.	0·50	0·72	0·94	1·2	0·66					2·4 ('48)
6	22 cm.		0·45	1·50	1·90	0·78	0·50				2·0 ('48)
7	23 cm.			0·50	1·10	0·76					
8	24 cm.				0·5		0·95				
9	25 cm.						1·00				

17 *cm. Group.*—From October the intensity of feeding goes steadily down till December when the group finally leaves the fishery. October feeding itself seems to be a point on a descending curve from July or August when feeding must have been very intense because of the availability of rich hauls of plankton (Chidambaram and Menon, 1945).

18 *cm. Group.*—In October the feeding is definitely low for fish of this size being only above 0·5 c.c. on the average. But in November and December they feed well. The availability of plankton again seems to have influenced the volume of feed in December. These fish leave the fishery by December.

19 *cm. Group.*—The fish of this group seem to be feeding well from October onwards. The feeding activity is high in November and in December the curve descends, and it is very low in January. It increases in February and in March again there is good feeding. The best month for their feeding activity is November; October and March being months in which they feed well.

20 *cm. Group.*—Making their first appearance in January they show very little feeding activity in that month. From January however, there is increased activity in feeding but the peak is reached only in April. In 1948, the only season when they appeared in November and December the feeding activity was high.

21 *cm. Group.*—This group appearing first in December shows extremely high feeding activity in that month. But in January there is a fall thereafter steadily increasing from month to month until April when again a period of intense feeding activity is noticed.

22 *cm. Group.*—In February when they first appear in the fishery the volume of feed is low. The feeding activity was found increasing in March and April with a fall in May. In 1948, when they appeared in December the feeding activity was high.

23 *cm. Group.*—The appearance of this group is confined to just the three months of March, April and May. The feeding activity is low in March and reaches the peak in April and in May the volume of feed is low but not so low as in March.

24 *cm. Group.*—For this size group data are available only for two unconnected months. In August they seem to be feeding well and in April the feed is low.

25 *cm. Group.*—Data is available only for August when their feeding seems to be fairly intense.

In all these size groups we notice a significant fact in their feeding activity. There are two periods of intense feeding. One is in October-December, and the other is in March-April. The absence of adequate data for the fish of various sizes in the months of June, July and August makes it difficult to say whether the fish about to spawn abstain from feeding even though there be enough of food as is certainly available in those months. Such data for the various size groups would afford conclusive proof in the matter of the feeding habits of the mackerels during the spawning season.

(*d*) *Spawning season*

Mackerel with ripening gonads are caught in the months of March, April and May. Very young sizes (4-5 cm. in length) of mackerel are met with in the months of July and August, or at the latest in September. These two facts would lead us to believe that spawning should occur sometime in the months intervening between April—when mackerel with ripe gonads are caught—and September when spent individuals are frequently met with.

From June 1940, there are records of very young mackerel measuring about 4 cm. having been caught (*Madras Fisheries Administration Report for* 1939–40). In July fish around 6 cm. are very common and these might have been the result of spawning earlier in the spawning season. Devanesen and John (1940) indicate that spawning of the mackerel begins sometime in June and continues till about the end of September. Chidambarm and Venkataraman (1946) have given a greater range and put it between May and September. Devanesen and Chidambaram (1948) feel that spawning is " protracted, lasting from June to September ". The concensus of opinion seems to be that spawning takes place between May and September. The presence of 4 cm. fish in June would suggest very early spawning, and fish with mature gonads continue to occur even in September.

Mackerel actually spawning have not been met with hitherto, within the fishing limits. Only ripe individuals with fully developed gonads corresponding to the fifth or sixth stages occur in the catches. If the mackerel spawned within the fishing limits then spawning individuals should have occurred in the catches in May or June. Devanesen and John's (1940) account of the discovery of what they believed to be mackerel eggs, gives the indication of the possibility of the spawning taking place near the shore at Tanur.

Devanesen and Chidambaram (1948) state that with the outbreak of the South-West Monsoon on the West Coast, the fish retire from inshore waters. The spawning admittedly extends up to September when the South-West Monsoon would be over. If they spawned in the inshore waters it is not likely that they will suddenly leave the spawning grounds and retire from the inshore waters. But that they retire from the inshore waters when the South-West Monsoon rains begin seems to be true. It would seem that this temporary forsakening of the inshore waters is towards the spawning grounds elsewhere. This leads us to believe that the spawning may take place at least beyond the present fishing limits, if not farther off.

It is of interest here to recall the spawning history of the European mackerel *Scomber scomber* L. McIntosh and Masterman writing in 1897

said that the mackerel congregate 'in vast shoals and these leaving the open sea migrate towards the land and discharge their eggs in inshore waters'. Meek (1916) stated substantially the same thing when he wrote that the spawning shoals migrate towards the coast about May, the males being usually the first to appear and spawning takes place when they arrive in coastal waters. Jordan in 1931 wrote that 'during May and June they spawn close to the coast'. In 1939 Steven and Corbin showed that 'spawning lasts from March until July or August with a maximum from mid-April to mid-May and occurs within the area of the continental shelf mainly offshore'. Corbin (1947) pointed out that 'spawning takes place throughout the Celtic Sea during the period, March to July. In the English Channel and also in the Irish Sea it is known to continue until August and probably in some years even until September well after the main activity has finished in the continental shelf area. At the beginning of the spawning in mid-March the area is small and is situated well to the South-West of Ireland in the waters overlying the edge of the Continental Shelf'. Steven (1949) writes of mackerel having spawned offshore and performed a return migration to the Coast. But it is too early for us to conclude that there is a parallel between the spawning of the Indian Mackerel and that of the European Mackerel. It is probable that the Indian Mackerel may spawn beyond the present fishing limits.

4. Variations in Fat Content of Mackerel

The different sizes of mackerel which dominate the landings in the different months of the fishing season have been indicated earlier in this paper. The four size groups, *i.e.*, fish below 12 cm. those between 12·1 and 16 cm., 16·1 and 20 cm. and 20·1 cm. and above have been taken for the study of fat variations, in veiw of the indication that they seem to form different age groups.

The percentages of fat content of the whole fish and the flesh given hereafter are on moisture-free basis.

The group comprising fish of 12 cm. and less are found in the months of July, August and September. Of these fish only a few analyses are on record and it is difficult to draw any conclusion therefrom (Table II). These immature fish have a very low fat value in the whole fish showing only 3·8 and 6·1% fat in July and August respectively.

The group comprising of fish between 12·1 and 16 cm. occur in the fishery between June and November. During the month of August, the fat content of this group of fish varies from 6·96% to 9·42% in the case of

TABLE II

*Analysis of mackerel—whole and flesh for the size group—*12 *cm. and less*

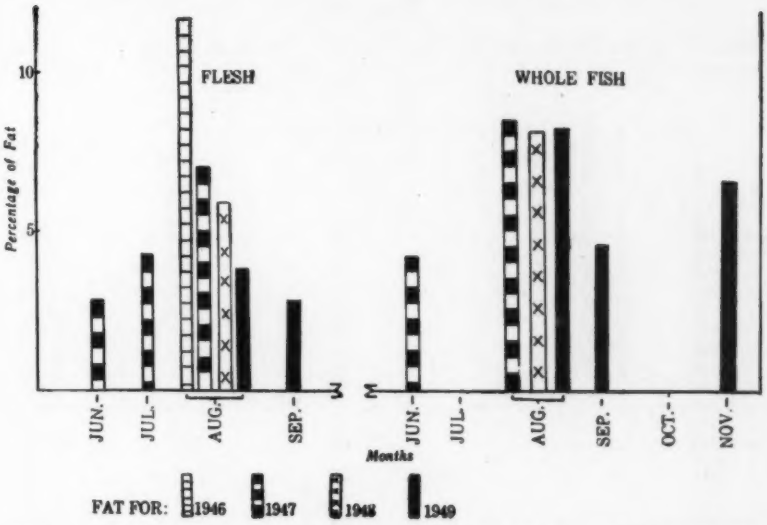
	Date	Length	Weight	Fat	
				On wet basis %	on water fee basis %
Flesh ..	11-8-1949	12·0 cm.	18 gm.	1·19	5·15
Whole fish ..	14-7-1947	11·1 cm.	18 gm.	0·82	3·80
	5-8-1949	11·7 cm.	15 gm.	1·43	6·11

whole fish and from 2·77 to 11·69% in the case of flesh (*vide* Table III and Graph 10). Fat peak in August is a result of good feeding in this season as plankton production is high in June, July and August (Chidambaram and Menon, 1945). In the analyses for this group it is seen that the whole fish fat is only slightly higher than the muscle fat.

TABLE III

Analysis of mackerel: whole and flesh for the size group 12·1 *to*16 *cm.*

Date	Length	Weight	Fat	
			On wet basis %	On water-free basis %
	Flesh			
	cm.	gm.		
10—8—1946 ..	14·5	37	2·83	11·69
26—6—1947 ..	13·3	20	0·69	2·86
14—7—1947 ..	13·2	18	1·00	4·37
12—8—1947 ..	13·5	26	1·68	7·04
3—8—1948 ..	15·8	39	1·04	4·37
23—8—1948 ..	15·0	40	1·91	7·67
5—8—1949 ..	13·3	20	1·04	4·30
5—8—1949 ..	14·2	25	0·64	2·77
22—8—1949 ..	14·6	32	1·21	4·52
14—9—1949 ..	13·7	26	0·83	3·46
14—9—1949 ..	14·6	34	0·71	2·20
	Whole Fish			
26—6—1947 ..	13·0	21	1·14	4·22
12—8—1947 ..	13·0	27	1·80	8·61
3—8—1948 ..	15·8	35	1·79	7·09
23—8—1948 ..	15·5	41	2·30	9·25
2—8—1949 ..	13·0	22	2·32	9·42
4—8—1949 ..	12·1	17	1·84	8·51
11—8—1949 ..	12·1	17	1·63	6·96
14—9—1949 ..	14·2	31	1·13	4·70
1-11—1949 ..	14·6	32	1·54	6·70



GRAPH 10. Fat variation for the size group 12·1 cm. to 16·0 cm. for the years 1946–49

The third group of fish between 16·1 and 20 cm. in size, contribute largely to the mackerel fishery in the months between October and January. This group includes both fish which are immature and those which are maturing. The fish of this group show their highest value for fat in the months of October and November; ranging between 18·01% and 30·91% in 1947, 17·5% and 19·5% in 1948, 19·82% and 26·31% in 1949 for the whole fish and the fat in flesh ranging from 3·59% to 7·35% in 1946, 12·80% to 21·71% in 1947, and 16·50% to 19·16% in 1949. The fat content is lowest in January falling down to 8·00% in whole fish and 2·90% in flesh. Fish of this size group show intense feeding during the months of October and November. A rise in fat content in October is perhaps a result of the heavy feeding. Towards January the intensity of feeding is less (Table IV). Like the fish of 12·1 to 16 cm. group, fat in whole fish is higher than fat in flesh (*vide* Graph 11).

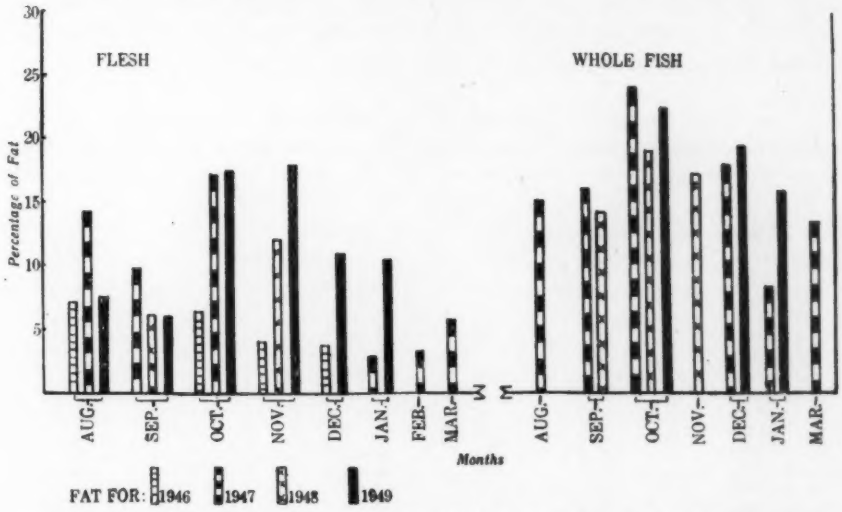
The group of fish, which are found with mature or maturing gonads, comprising of sizes above 20 cm. form the only catch during the months from February to the end of the season though these occur in fair quantities in November and December. The fat value of whole fish in this group reaches its maximum of 35·5% in November. Only three analyses one in each of the three years 1947, 1948 and 1949 for November are available. These fish analysed were still in the earlier stages of gonadial maturity. This

TABLE IV

Analysis of mackerel—whole and flesh for the size group 16·1–20·0 *cm.*

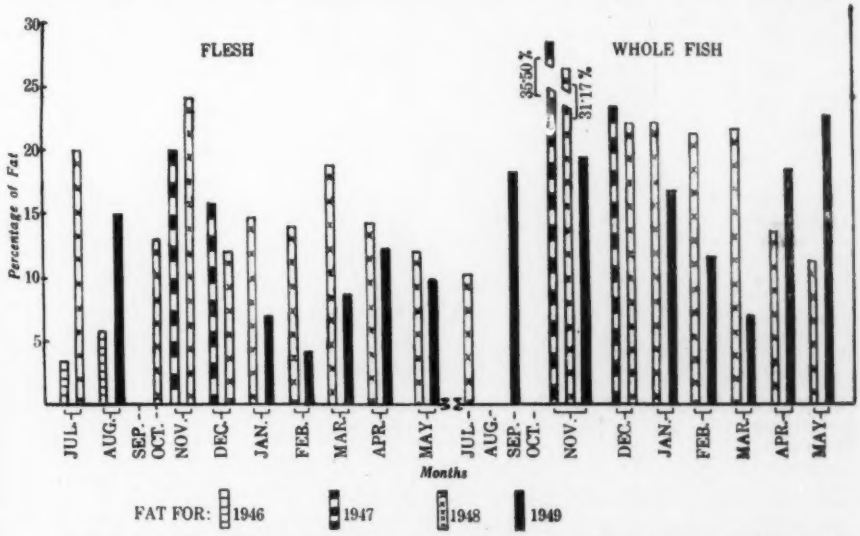
Date	Length in cm.	Weight in gm.	Fat	
			On wet basis %	On water-free basis %
	Flesh			
20—8—1946 ..	19·5	90	1·58	7·16
1–10—1946 ..	17·5	67	1·86	7·35
14–10—1946 ..	18·0	67	1·33	5·79
1–11—1946 ..	18·0	67	0·81	3·59
14–11—1946 ..	17·5	61	1·09	5·00
2–12—1946 ..	17·5	60	1·00	4·48
17–12—1946 ..	17·8	60	0·71	3·32
15—1—1947 ..	18·5	62	0·71	2·90
17—2—1947 ..	19·0	69	0·83	3·47
14—3—1947 ..	19·5	80	1·60	6·10
4—8—1947 ..	19·8	88	3·87	14·41
1—9—1947 ..	18·5	69	2·55	10·45
16—9—1947 ..	17·5	62	2·32	9·37
1–10—1947 ..	18·5	70	3·20	12·80
16–10—1947 ..	19·3	82	5·93	21·71
8—9—1948 ..	17·8	65	2·07	7·28
22—9—1948 ..	16·8	51	1·39	5·48
26–11—1948 ..	17·1	55	3·39	12·31
25—1—1949 ..	19·9	79	3·05	10·60
22—8—1949 ..	16·6	52	1·48	5·27
22—8—1949 ..	18·7	75	2·93	10·45
1—9—1949 ..	19·9	87	2·13	8·28
14—9—1949 ..	16·2	46	0·96	3·86
4–10—1949 ..	17·6	63	5·30	16·50
25–10—1949 ..	18·3	83	5·65	19·16
10–11—1949 ..	18·9	74	5·55	17·68
12–11—1949 ..	18·8	78	4·92	18·62
5–12—1949 ..	17·9	66	4·57	16·64
5–12—1949 ..	18·1	64	2·14	7·62
15–12—1949 ..	17·7	70	2·50	9·60
	Whole fish			
20—1—1947 ..	18·2	76	1·90	8·00
1—3—1947 ..	19·3	75	3·60	13·80
4—8—1947 ..	19·8	88	4·36	15·68
1—9—1947 ..	19·0	80	4·74	18·21
16—9—1947 .	17·5	62	3·52	15·05
1–10—1947 ..	18·5	70	4·95	18·01
16–10—1947 ..	19·3	82	9·49	30·91
2–12—1947 ..	19·0	75	5·17	18·34
8—9—1948 ..	17·5	65	3·81	14·26
22—9—1948 ..	16·8	51	3·78	15·26
16–10—1948 ..	20·0	95	5·43	19·50
26–11—1948 ..	17·1	55	4·77	17·50
25—1—1949 ..	19·9	79	4·44	16·29
4–10—1949 ..	17·5	58	5·80	19·82
17–10—1949 ..	18·2	65	6·87	23·66
22–10—1949 ..	17·7	62	7·24	24·22
25–10—1949 ..	17·5	69	5·40	19·88
25–10—1949 ..	19·0	63	7·99	26·31
5–12—1949 ..	17·2	61	4·74	16·17
5–12—1949 ..	19·4	82	6·79	23·08
15–12—1949 ..	18·3	71	5·43	19·79

Percentage of Fat



GRAPH 11. Fat variation for the size group 16·1 cm. to 20·0 cm. for the years 1946–49

group shows a high value of fat content for a second time in the period, March to May (*vide* Graph 12). Feeding activity during this period tends to be on the rise with a maximum in April. The 20 cm. to 23 cm. groups



GRAPH 12. Fat variation for the size group 20·1 cm. and above for the years 1946–49

were all heavily feeding in April (Table V). The gonads are maturing and fish in the third or further stages of gonadial development are met with. These fish are due to spawn in the ensuing spawning season.

TABLE V

Analyses of mackerel whole fish and flesh for the size group 20·1 cm. and above

Date	Size in cm.	Weight in gm.	Maturity	Fat	
				On wet basis %	On water-free basis %
		Flesh			
8—7—1946 ..	21	105	Spent	0·69	3·05
1—8—1946 ..	23·5	..	V	1·61	5·75
3—11—1947 ..	21·5	115	II & Developing	8·50	27·14
25—11—1947 ..	21·5	90	II & III	3·34	12·83
17—12—1947 ..	20·2	88	I & II	3·98	15·69
7—1—1948 ..	20·2	88	II & III	3·05	11·92
16—1—1948 ..	21·5	104	II & III	4·71	17·82
11—2—1948 ..	22·3	131	III & IV	3·76	13·91
3—3—1948 ..	21·4	116	III	6·44	22·12
13—3—1948 ..	22·4	128	IV	4·19	15·60
16—4—1948 ..	22·5	141	V	3·98	14·31
10—5—1948 ..	22·5	123	VI	3·10	12·16
2—7—1948 ..	23·8	162	VI	5·29	19·80
16—10—1948 ..	20·2	92	Trace	3·72	13·39
25—10—1948 ..	20·1	92	(Not available)	3·51	12·51
8—11—1948 ..	20·8	107	Trace & I	7·86	24·02
9—12—1948 ..	20·9	102	Not available)	3·61	12·06
12—1—1949 ..	20·9	91	I	1·77	7·03
23—2—1949 ..	21·1	87	I	1·03	4·20
26—3—1949 ..	21·3	106	II, III & IV	2·30	8·80
19—4—1949 ..	21·7	113	III & IV	3·10	12·40
7—5—1949 ..	21·8	121	IV	2·14	8·18
16—5—1949 ..	22·3	124	IV	3·13	11·69
2—8—1949 ..	23·4	159	V	4·10	14·78
		Whole fish			
3—11—1947 ..	21·5	82	II & III	12·50	35·50
17—12—1947 ..	20·2	88	II & III	6·92	23·50
7—1—1948 ..	20·2	88	II & III	6·50	22·09
16—1—1948 ..	21·5	104	II & III	6·42	22·30
11—2—1948 ..	22·3	131	IV	6·09	21·40
3—3—1948 ..	21·4	116	III	6·16	20·96
13—3—1948 ..	22·4	128	IV	6·67	22·48
16—4—1948 ..	22·5	141	V	3·88	13·82
18—5—1948 ..	22·3	124	VI	3·06	11·47
2—7—1948 ..	23·8	162	VI	3·06	10·23
8—11—1948 ..	20·8	107	I, Trace	9·63	31·17
7—12—1948 ..	21·0	105	(Not available)	6·09	21·99
12—1—1949 ..	20·9	91	I	4·68	16·85
7—2—1949 ..	20·9	88	I	3·10	11·68
4—3—1949 ..	21·2	86	I	1·75	7·09
12—4—1949 ..	21·7	113	III	5·00	18·50
16—5—1949 ..	22·3	124	IV & V	7·40	22·60
1—9—1949 .	21·1	122	II	5·11	18·25
12—11—1949 ..	20·1	92	I	5·83	19·54

The table showing the variation in fat content of mackerel just prior to spawning is given below:—

TABLE VI

Variation in fat content of mackerel about the spawn

Date	Length in cm.	Weight in gm.	Fat	
			On wet basis %	Water-free basis %
(*a*) March to July—				
		Flesh		
8—7—1946 ..	21·0	105	0·69	3·05
3—3—1948 ..	21·4	116	6·44	22·12
13—3—1948 ..	22·4	128	4·19	15·60
16—4—1948 ..	22·5	141	3·98	14·31
10—5—1948 ..	22·5	123	3·10	12·16
2—7—1948 ..	23·8	162	5·29	19·80
26—3—1949 ..	21·3	106	2·30	8·80
12—4—1949 ..	21·7	113	4·33	17·06
7—5—1949 ..	21·8	126	2·14	8·18
16—5—1949 ..	22·3	124	3·13	11·69
		Whole fish		
3—3—1948 ..	21·4	116	6·16	20·96
13—3—1948 ..	22·4	128	6·67	22·48
16—4—1948 ..	22·5	141	3·88	13·82
18—5—1948 ..	22·3	124	3·06	11·47
2—7—1948 ..	23·8	162	3·06	10·23
4—3—1949 ..	21·2	85	1·75	7·09
12—4—1949 ..	21·7	113	5·00	18·50
16—5—1949 ..	22·3	124	7·40	22·60
(*b*) August to September—				
		Flesh		
1—8—1946 ..	23·5	..	1·61	5·75
2—8—1949 ..	23·4	159	4·10	14·78
		Whole fish		
1—9—1949 ..	21·1	122	5·11	18·25

The younger size groups below 12 cm. are represented in the fishery from July upto September. The sizes above 12 cm. only are found in the catches after September. In October-November the fat content in the whole fish is at its peak. In this period predominantly, fish of sizes between 15 and 19 cm. constitute the fishery. They are in the first two stages of gonadial maturity. This high storage of fat in October may be the result of the active feeding in the preceeding months of June, July and August, when phyto-plankton is abundant.

The variations in fat exist from year to year, though the maximum is attained at the same period every year.

This is evident from the following observations:—

In 1947 the whole fish fat (30·91%) was maximum in October for size group 16·1 to 20 cm. In October 1948, the fat content (19·50%) was the maximum for this size group. In the same month of 1949 the fat content (26·31%) was the maximum for the above mentioned group.

Again for the group above 20·0 cm. in 1947, the whole fish fat was 35·50%, whereas for 1949 it was 19·54% in the same month, *viz.*, November.

The variation in fat content of size group 16·0 cm. and above, is much greater than the variation in size group below 16·0 cm. This is brought about clearly in the table furnished below:—

	Fat in whole fish	
	Wet basis	Water-free basis
12 cm. and less	0·82—1·43%	3·80—6·11%
12·1 cm. to 16 cm.	1·13—2·32%	4·22—9·42%
16·1 cm. to 20 cm.	1·90—9·49%	8·00–26·30%
20·1 cm. and above	1·70–12·50%	7·09–35·50%
	Fat in flesh	
I ..	1·19%	5·15%
II ..	0·64—2·83%	2·77–11·69%
III ..	0·71—5·91%	2·90–21·71%
IV ..	0·69—8·50%	3·05–27·14%

It can be observed that whereas a variation of 10·60% is observed in fish above 16·1 cm. there is hardly a variation of more than 1·50% in smaller fish. The fish measuring more than 16 cm. show very wide variation from the minimum to the maximum than those which are smaller in size.

5. DISCUSSION

The various factors which influence the variations in fat content of fish are to be found in the sizes, age, races, sexes, nature of food and feeding activity, spawning conditions, season and locality. In addition it is quite frequently observed that there are variations amongst individuals. In the present study on mackerel the results of a few analyses of the individuals are presented in Table VII.

The variations between individuals of the same size groups and under the same conditions of gonadial maturity and sexes are noticed, and these variations are found to a greater extent in the larger size groups. Further work may perhaps aid us in appraising of the degree of variations due to the different factors. Similar variations among individuals have been indicated by Atwater (1888), Hjort (1914), Elsaby (1937) and Stansby and Lemon (1941).

TABLE VII

Analyses of mackerel flesh to show individual variations in fat content

Date	Length	Maturity	Fat (wet basis) %
5—8—1948 ..	13·5	Indeterminate	0·97
5—8—1948 ..	13·7	do	0·67
14—9—1949 ..	13·5	do	0·74
14—9—1949 ..	16·0	♂ I	0·96
14—9—1949 ..	16·3	♀ Trace	0·96
17—10—1949 ..	16·8	♀ Trace	4·22
4—10—1949 ..	17·0	♂ Trace	4·91
10—11—1949 ..	18·5	♂ I	2·44
10—11—1949 ..	19·8	♂ I	2·95
15—12—1949 ..	17·6	♀ II	1·99
15—12—1949 ..	17·8	♂ II	3·85
3—2—1950 ..	20·1	♂ II	6·29
3—2—1950 ..	19·3	♂ II	3·83
20—2—1950 ..	20·0	♀ II	0·93
6—3—1950 ..	21·0	♂ III	2·78
6—3—1950 ..	20·5	♀ III	4·53
1—4—1950 ..	20·6	♂ III	7·00
1—4—1950 ..	20·6	♂ III	2·64
1—4—1950 ..	20·9	♂ III	3·51
1—4—1950 ..	20·4	♀ III	3·76

The mackerel of larger sizes show greater percentage of fat than the smaller ones (less than 16 cm.), in the same season. The averages of the results of analyses in the same months during the period 1946–49 for the two groups of sizes, *viz.*, less than 16 cm. and more than 16·1 cm. are presented to illustrate this in the following table:—

TABLE VIII

Range of fat variations in groups 16 cm. and less and above 16·1 cm.

Months	Sizes less than 16·0 cm.				Sizes more than 16·1 cm.			
	Whole fish		Flesh		Whole fish		Flesh	
	Wet%	Water-free %	Wet %	Water-free %	Wet %	Water-free %	Wet %	Water-free %
August ..	1·87	8·00	1·36	5·78	3·47	12·65	..	..
September ..	1·13	4·70	1·53	5·90	3·96	11·94	..	..
October ..	..	..	..	..	7·58	25·14	3·85	13·37
November ..	1·49	6·10	0·93	3·80	8·12	22·19	4·04	14·36
December ..	..	..	..	..	5·57	19·72	2·74	10·38
January ..	..	..	..	..	6·96	24·14	2·32	8·78
February ..	..	..	..	..	6·43	23·77	1·95	7·81
March ..	..	..	..	..	3·91	14·19	2·96	10·78
April ..	..	..	..	..	4·60	16·19	4·15	15·73
May ..	..	..	..	..	4·06	14·02	2·88	10·80
June ..	1·14	4·22	0·69	2·86	..	..	..	..
July ..	0·82	3·80	1·00	4·37	3·06	10·23	..	..

The low fat content in the smaller size groups is due to the fact that they are in a rapidly growing condition and as such the fish of these groups are not having much of reserve fat. This observation of ours coincides with similar observations made by Lovern and Wood (1939) in the case of immature herrings of the Scottish waters. The range of variations in fat content is also greater in the larger groups than in the smaller ones. Similar variations amongst smaller and larger sizes have been recorded by Lovern and Wood (1937) in the case of herrings and Stansby and Lemon (1941) in the case of Atlantic Mackerel.

In October-November and in March-April the fat contents are at the maximum during the different years under consideration. In October-November the percentage of fat is at its peak in all the size groups constituting the fishery. This high storage of fat is naturally due to the intensive feeding in the preceding months when the planktonic food is plentiful. Wimpenny (1938) has indicated that the accumulation of fat owes its origin to the food previously eaten by the fish. Working on herrings, Lovern and Wood (1937) found them in a lean condition in winter, and with food becoming abundant in April and the two following months they feed heavily resulting in the storage of fat in the flesh and around the intestines with a high value in July; both in immature and adult individuals the fat variations had a striking relationship with the availability of plankton. Wilson (1939) working on the fat content of flounders has indicated the abundance of fat after intense feeding during summer and reduction in the fat content after the winter fast.

The second peak in the value of fat content in Indian mackerel in March-April is influenced by the high intensity of feeding during the period and also by the advancing condition of development of the gonads prior to spawning. The feeding activity of the larger sized mackerel is very intense in April coinciding with the minor peak of production of plankton. The heavy reserves of fat during this period are naturally explained in view of the spawning activity in the months to follow when feeding also may be restricted.

Milroy (1906; 1908) in a study of the muscles and gonads of the Loch Fynne herrings observed 'a rapid rise in the percentage of fat in the muscles during the several months prior to the time when rapid growth of ovaries and testes began.' Channon and Saby (1932) indicated a rise in the fat content of herring muscle before spawning followed by a fall after spawning. Lovern and Wood (1937) found a similar trend of variations in fat content before and after spawning in the case of Scottish herring. Oya, *et al.* (1937) have showed seasonal variations in the fat content in *Sardinia mela-*

nosticta in summer and winter. Wilson (1939) had also referred to a similar variation in the case of flounder.

Though samples of Indian mackerel could not be analysed just after spawning, the analyses of spent individuals made on a few occasions indicate the fall in fat content after spawning as could be anticipated and as observed elsewhere by other workers (Milroy, 1906, 1908; Bruce, 1924; Channon and Saby, 1932; Lovern and Wood, 1939; Oya, *et al.*, 1937; Wilson, 1939; and Arevalo, 1948).

There have been references relating to the amount of fat during the migration of *Scomber scombrus* by Stansby and Lemon (1941) wherein they suggest that the fish may not feed during their long distance migration for spawning.

Lovern and Wood (1937) have suggested that in the " latter stages of maturation little food is taken by the herrings, so that the reserves of fat may not be used entirely to meet the demands of the reproductive system." This suggestion perhaps is because of lack of feeding during those months. However this may require some further observations in the light of a recent indication by Steven (1949) that the Atlantic mackerel migrating towards spawning grounds will feed, if food is available. But in the case of herrings a rapid decline in fat content subsequent to spawning has been definitely noticed. In the case of Indian mackerel we are not yet in a position to get samples adequately to comment on the variations.

Sekharan (1949) working on the fat variations in the muscles of the rainbow sardine, *Dussumieria acuta* (Cuv. and Val.), on the Madras Coast, has observed a maximum in October with a smaller rise in April-May and indicated the possible cause for the rise and fall due to the feeding activity and especially the inclusion of teleosts in its diet and also the effect of maturity of gonads. In the case of Indian mackerel, the fat variation has been attributed to the changes in the intensity of feeding activity, the conditions of maturity of the gonads, etc., and in this paper as the conditions of fat in the muscle and the whole fish were analysed, it was possible to indicate the degree of fatness in the gonads and explain the conditions. Regarding the kind of food which is responsible for increased fat content, the work is in progress; however it can be said that mackerel more than 10 cm. in length have not been reported to have fed on young fish and they are mainly plankton feeder and further work under progress will throw more light on the different organisms in the food which contribute the fat.

In the couse of this investigation, it may not be out of place to indicate that there is a great range of variation in the fat content of mackerel of the

two sexes and in the gonads at different stages of the maturity. The available data are presented below:—

TABLE IX

Fat of Gonads and fat variation in the two sexes at different stages of maturity in mackerel

Date	Size of fish in cm.	Maturity stage	Fat in gonads wet basis %	Fat in fish wet basis %	Whole fish wet basis %
29–12–1948 ..	20·9	♀ I	5·78	2·29	6·41 Average
29–12–1948 ..	20·9	♂ Trace	1·38	2·29	do
24–3–1949 ..	21·3	♂ II—III	4·59	2·45	1·75
do ..	do	♀ II—III	5·11	2·45	
28–3–1949 ..	21·3	♂ III–IV	5·69	2·16	..
12–4–1949 ..	do	♀ IV	4·77	2·16	..
do ..	21·7	♀ IV	4·29	4·33	..
16–5–1949 ..	22·3	♀ IV–V	5·77	3·13	7·40
2–8–1949 ..	23·4	♂ V	1·92	4·10	..
do ..	do	♀ V	5·33	do	
6–3–1950 ..	20·5	♀ III	4·30	4·03	5·89
do ..	do	♂ III	3·27	do	do
16–3–1950 ..	20·9	♂ III	0·66	5·32	5·00
do ..	do	♀ III	8·40	do	6·95
1–4–1950 ..		♂ III	3·61	5·63	5·41
do ..		♀ III	3·78	3·51	2·86

6. SUMMARY

It is observed that there are two peaks of increase in fat content. One is in the months of October-November when the catches comprise mostly 16 to 20 cm. size group, and another is in March-April when the group comprises of sizes 20 cm. and above.

The major fatty condition is attributable to the feeding activity of all sizes of fish. The minor fatty condition during March-April is due to the intensive feeding of the adult group of fish.

Any fish caught in October-November (mostly 16·1 to 20·0 cm. and the samll proportion of 20·1 cm. and above size) is quite fatty and this fat condition must be taken into consideration in its proper utilisation for salting, freezing, canning, fishmeal preparation, etc. The fish that are fatty during March-May are above 20·1 cm. and are almost mature. The fish are fatty before spawning and lean after spawning.

The fat in immature ones (16·0 cm. and less) never rises above 3% in flesh whereas in the mature ones it is as high as 8·5%. The corresponding figures for the whole fish are 2·32% and 12·5%.

The variations in fat content of individuals according to sexes and gonads, and at different times of the year are also indicated.

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THE MORPHOLOGY OF *NICHOLLSIA KASHIENSE* CHOPRA AND TIWARI (CRUSTACEA : ISOPODA PHREATOICOIDEA)*

Part I. The Head and Endophragmal System

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Introduction

Earlier work on phreatoicid morphology.—Except for brief references by Smith (1909, pp. 71–73) and Barnard (1925, pp. 31–39, Fig. 9) on the foregut of some phreatoicids, I have not come across any reference in connection with the internal morphology of phreatoicid Isopods. Nicholls (1943 and 1944), in his monographs on the sub-order Phreatoicoidea, has given excellent description of external features but beyond the presence or absence of a typhlosole in the intestine, he has not dealt with the internal anatomy at all. The present paper is an attempt to fill in this lacuna in phreatoicid morphology.

The type chosen for this study is *Nichollsia kashiense* Chopra and Tiwari (1951), the only representative of the Phreatoicoidea so far recorded from India. This paper deals with the morphology of the head and endophragmal skeleton.

Material and Methods.—Material for this study was collected from wells at Banaras (U.P.) during July 1949. The internal skeleton was examined under high power binoculars after dissecting the specimens treated with cold solution of caustic potash.

Earlier work on Isopod head.—The most important work on the morphology of Isopod head was done by Jackson (1926 and 1928). In his first work he dealt with the detailed morphology of the head of *Ligia oceanica* and subsequently he gave comparative accounts of the head in certain selected genera of terrestrial Isopods. Among other important references in connection with Isopod head may be mentioned Sars (1867) who figured the " maxillo-skeletal framework " of *Asellus aquaticus*, Milne-Edwards and Bouvier (1902) and Lloyd (1908), on *Bathynomous giganteus* Edw. and Bouv., and Tait (1917) on *Glyptonotus antarcticus* Eights.

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As Jackson's account of *Ligia oceanica* is by far the most complete, I have followed the terminology proposed by him and in most structures comparison has been made with *Ligia* only.

Acknowledgement.—I owe a deep sense of gratitude to Dr. B. N. Chopra, for having gone through the manuscript of the paper and for helpful suggestions.

THE HEAD OF *Nichollsia kashiense* CHOPRA AND TIWARI

External features.—The head of *N. kashiense* is rectangular in dorsal view (Pl. V, Fig. 2, *d.h.*). It is about a third longer than broad, and its depth equals the breadth. The dorsal surface is evenly rounded. The posterior edge is convex, and anteriorly the concave margin is produced into a lateral projection (*lat. pr.*) on each side. The sides of the head, when viewed dorsally, are parallel. In lateral view the head is roughly pentangular.

The ventro-lateral edge of the head is horizontal in post-mandibular region (Pl. V, Fig. 3, *po. mnd.*) but it obliquely ascends upwards in the mandibular region (*reg. mnd.*). The post-mandibular region is about as long as the mandibular region.

The following structures can be recognised on the outer surface of the head capsule.

(i) *The occipital groove* (Pl. V, Figs. 2 and 3, *occ. gr.*).—The occipital groove (= cervical groove of Nicholls) is absent dorsally. On each side, towards the posterior region of the head, a shallow vertical groove forms the lateral arms of the occipital groove. Each arm is shallow towards its dorsal end but becomes somewhat deeper as it descends. Each arm ends about the middle of the lateral surface at the point where the antero-lateral projection of the first peræon segment is fused with the head.

The occipital groove does not continue inside the cavity of head capsules, as a calcified septum forming the tergal ala. It only forms a shallow ridge which is produced into a slender finger-shaped projection, at its lower end.

The incomplete occipital groove marks the anterior boundary of the maxillipedal segment, which appears to have undergone a great degree of fusion with the cephalon in this species.

(ii) *The genal groove* (Pl. V, Fig. 3 and Text-Fig. 1 *a*, *gr. gen.*).—It is a shallow crescentic groove, starting from the point where the occipital groove ends, and descending obliquely downwards, and then running forwards, it terminates in the posterior portion of the mandibular region.

The gena is flat, without any fossa.

(iii) *The marginal line* (?) (Pl. V, Figs. 2 and 3, *lin. ma.*).—Jackson describes the marginal line in *Ligia oceanica* as follows:—" From the anterior edge of the groove a well defined ridge passes forward round each side of the head beneath the eyes. In front of the eyes it passes over a knob which is moderately well defined in *Ligia* (the *antennary tubercle*) and then falls vertically until it reaches the upper margin of the mandible. At this point it turns forward and inward to pass to the front of the face, until it is lost at the junction of the anterior apophysis (articular peg) of the mandible with the face."

In *N. kashiense*, a shallow horizontal groove in the sub-ocular region[1] (Pl. V, Figs. 2 and 3 and Text-Fig. 1 *a*, *lin. ma.*) is probably homologous with the marginal line of *Ligia oceanica*. This groove is very short and after running forwards for some distance it turns and falls below to meet the ventral edge of the head at the notch in which the fulcral process of mandible articulates with the anterior end of head.

(iv) *Supra-antennary line* (Pl. V, Fig. 2, *lin. ant.*).—Frontal line is absent in all aquatic Isopods and the supra-antennary line is a structure of great importance in them (Jackson, 1928, p. 562). In *N. kashiense*, as in other phreatoicids, the supra-antennary line is well developed. This line is seen in dorsal view as a concave ridge marking the anterior boundary of the head, in front of which the face descends vertically. This ridge is shallow in the middle but is produced on each side into a prominent triangular projection (Pl. V, Figs. 1, 2 and 3, *lat. pr.*). The lower arm of the ridge passes backwards, and is continuous below with the frontal lamina.

(v) *The frontal lamina* (Pl. V, *lam. fr.*).—The sockets of the second antennæ are bound below by a plate, the frontal lamina, which between the antennal sockets projects as a quadrangular plate fused with the face above. Below these sockets, the lamina extends as a horizontal plate and externally, as a bulbous flap flanking the socket.

(vi) *Tne Clypeus* (Pl. V, Fig. 1, *Cl.*).—The Clypeus is clearly distinguished from the frontal lamina. It is an assymmetrical quadrangular plate, broader in the left half. On each side the clypeus articulates with the fulcral process of the mandible by a lateral process (Pl. V, Fig. 1, *pr. lat.*) which is larger on the left side.

(vii) *The sockets of antennule and antenna* (Pl. V, Fig. 1, *ant.* 1 and *ant.* 2).—After removal of the antennules and antennæ, the face appears as

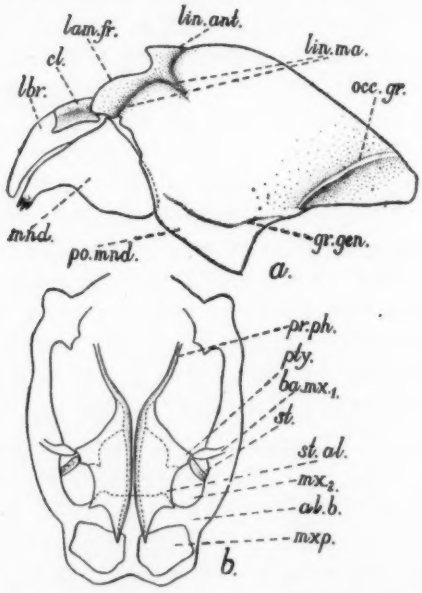
[1] The eyes are absent in this species. A similar groove is, however, present in many other phreatoicids with eyes, in the sub-ocular region.

a sub-circular structure bound below and on the side by the frontal lamina, and above by the supra-antennary line. The sockets of antennæ (*ant.* 2) are large and separated by the quadrangular frontal lamina in the middle. The smaller antennulary sockets have not shifted so close between the antennæ as in *Ligia*, and an oblique transverse prolongation of the frontal lamina (*st. ant.*) separates the antennary and antennular sockets. The portion of the face between antennulary sockets dips down in the form of a V-shaped ridge.

MAXILLO-STERNAL FRAMEWORK

(Pl. V, Fig. 4 and Text-Fig. 1, *b*)

The maxillo-sternal framework of *N. kashiense* appears to be somewhat simpler than in *Ligia* and *Glyptonotus*. In *Nichollsia*, the oral appendages are horizontal (and not vertical as in *Ligia*), and their articular sockets follow one after another, although the maxillula is still situated somewhat lateral to the maxilla. The ventral surface of the head consists of chitinous membrane in which a system of calcified bars has developed to support the oral appendages and their muscles. This system of calcified bars of *Nichollsia*, the maxillo-sternal framework, is similar to that



TEXT-FIG. 1. Head of *Nichollsia kashiense* Chopra and Tiwari; (*a*) lateral view; (*b*) Endophragmal system (semi-diagrammatic), seen from above, after removal of the dorsal part of the head; *ba. mx.* 1., basal endite of maxillula. (For the rest see the explanation of abbreviations).

of *Ligia oceanica* in general features. The following are the important structures in maxillo-sternal framework.

(i) *The median ba* (Pl. V, Fig. 4, *med. b.*).—The median bar stretches longitudinally in the middle, and gives rise on each side to paired bars. The dorsal surface of this bar is grooved and there is a corresponding ridge on its ventral surface. The median bar is fused behind with the postero-ventral edge of the maxillipedal somite, and it extends forwards longitudinally, separating the articular sockets of maxillipeds from each other. In front of the alar bar, with which it is firmly fused, the median bar sharply dips down and then continues forward till it branches into two, each branch entering one lobe of the paragnaths, and forming its sickle-shaped skeleton (*sk. par.*).

(ii) *The maxillulary sclerite* (Pl. V, Fig. 4, *mx. scl.* 1).—Just before the median bar bifurcates to enter the paragnaths it gives rise, on each side, to a slender calcareous rod, which runs transversely across the floor of the head and joins the inner endite of the maxillula.

(iii) *The maxillary sclerite* (Pl. V, Fig. 4, *mx. scl.* 2).—Somewhat behind the origin of maxillulary sclerites, the median bar gives rise to another pair of transverse bars, one on each side, the maxillary sclerite. Each maxillary sclerite, turns backwards and downwards, and articulates with the maxillo-pterygoid process of sternal alæ (Pl. V, Fig. 4, *pty.*) which is fused with a long finger-shaped projection (Pl. V, Fig. 4, *st.*) arising from the ventral edge of the head in front of the alar bar.

(iv) *The alar bar* (Pl. V, Fig. 4, *al. b.*).—The alar bar is a stout calcareous transverse bar forming the anterior boundary of the maxillipedal sockets, and fused with the median bar in the middle. The alar bar is broad in the middle and concave on its dorsal surface. It is rigidly fused on the sides with the ventral edge of the head. Unlike *Ligia oceanica*, *Glyptonotus antarcticus* and *Bathynomus giganteus* the alar bar is not connected with the tergal alæ (which are very vestigeal in this species).

(v) *Incomplete maxillary sternite* (Pl. V, Fig. 4 and Text-Fig. 1 *b*, *st.*).—Somewhat in front of the alar bar the ventro-lateral edge of the head gives rise on each side to a long finger-shaped, calcified, obliquely transverse projection. This projection is immediately in front of the maxilla and it forms a part of the anterior boundary of maxillary somite. On its anterior side the socket of the maxillula begins. To this projection is fused the maxillo-pterygoid process of the sternal alæ. Near the point of its junction, the maxillo-pterygoid process receives the basal endite of the maxillula in front, and the maxillary sclerite behind.

This finger-shaped process, thus, from its position and relationships appears to be the incomplete maxillary sternite.

(vi) *Articular sockets of the oral appendages*.—The maxillipeds are surrounded in front by the alar bar, behind by the posterior edge of maxillipede somite, on the outer side by the ventral edge of head, and in the middle by the median bar. The maxillary socket is bound behind by alar bar, on the side by the wall of the head, in front partly by the incomplete maxillary sternite and partly by the maxillary sclerite, and in the middle by the median bar. The sockets of maxillula are membranous. Anterior limit of maxillulary sockets is the maxillulary sclerite, and posteriorly the maxillary sternite and maxillary sclerite separate the maxillary and maxillulary sockets.

ENDOPHRAGMAL SYSTEM

In *Ligia*, *Bathynomus* and *Glyptonotus* the endophragmal system consists of tergal and sternal alæ. The tergal alæ are downward continuation of the occipital groove, stretching vertically across the cavity of head, and continuing up to the alar bar below.

In *Nichollsia kashiense* the tergal alæ are very vestigeal. The occipital groove is continuous on the inner surface of the head as a shallow ridge, being produced into a finger-shaped process at its lower end, which projects freely into the cavity of the head. This process is the vestigeal tergal ala.

The sternal alæ (Pl. V, Fig. 4, *st. al.*) are a pair of horizontal semitubular plates, stretching along the cavity of the head, and joined along their mesial edges by fibrous material. This structure is very much like that in *Ligia oceanica* from which it differs in the absence of infero-latero-pterygoid process and the alar process. Anteriorly each sternal ala is produced into a pharyngeal process (Pl. V, Fig. 4, *pr. ph.*) which is fused dorsally with the head, behind the marginal line. The maxillo-pterygoid process (Pl. V, Fig. 4, *pty.*), as already stated earlier, is fused with the finger-shaped incomplete maxillary sternite. The posterior part of each ala, which is separated from the anterior portion by a transverse line, projects freely into the cavity of the head in the maxillipedal region.

DISCUSSION

In the presence of a well-developed supra-antennary line and absence of the frontal line, *Nichollsia* resembles other aquatic Isopods. The supra-antennary line of *Nichollsia* is raised into a prominent ridge on each corner, and this is a more or less common feature in all Phreatoicids.

In the absence of cervical groove on the dorsal side and presence of very vestigeal tergal alæ, *Nichollsia* presents a greater degree of the fusion of maxillipedal segment with the cephalon. The absence of tergal alæ in this species, however, appears to be due to its comparatively simpler food habits which do not involve great stress on the mandibles, which are strengthened in *Ligia, Bathynomous* and *Glyptonotus* by insertion of their muscles on the anterior face of tergal alæ.

The assymmetrical clypeus is an important characteristic of Phreatoicid Isopods in which generally the left mandible is larger than the right, and the organs involved in this assymmetry are the labrum and clypeus. Since no other parts are apparently involved, it appears very probable that the assymmetry is restricted to the mandibular somite only. This assumption, if correct, would support Dolfuss's (*fide* Jackson, 1926, p. 894) contention that the clypeus (his metepistome) is mandibulary sternum. Jackson also, rather hesitatingly, thinks the clypeus as probably representing the mandibulary sternum.

The antennule of *Nichollsia* has not migrated as far backwards as that of *Ligia* and other terrestrial Isopods, and the antennular sockets are rather large and fairly well apart from each other. This, however, appears to be mostly due to the length of the antennule which is far better developed in *Nicholisia*. If the clypeus is taken as representing the mandibular somite, then the antennulary and antennal somites are restricted to the portion above the clypeus.

In the maxillo-sternal framework, *Nichollsia* resembles *Ligia* to some extent. The maxillulary sclerite of *Nicholisia* agrees completely with that of *Ligia*. In the maxillary sclerite, however, there is some difference. According to Jackson the maxillary sclerite in *Ligia* originates from the alar bar. It first runs inwards and then forwards along the median bar, but distinct from it, and reaching the level of paragnaths it again turns back, and finally joins the maxillo-pterygoid process of sternal alæ. In *Nichollsia* I could trace only the anterior portion of this sclerite.

The alar bar is very prominent and stout structure in this species.

The presence of a finger-shaped process arising from the ventral edge of the head in front of the alar bar, and probably representing an incomplete maxillary sternite is interesting and singular in *Nichollsia*.

The endophragmal system of *Nichollsia* is simpler than that of *Ligia, Glyptonotus* and *Bathynomus*. The tergal alæ are vestigeal, and the sternal alæ although resembling those of *Ligia*, lack the anterior alar process and the hinder infero-lateral pterygoid process.

COMPARISON WITH OTHER PHREATOICIDS

A careful study of Nicholls' description and figures of various Phreatoicids shows that the head in all Phreatoicids is built on the same general plan.

The supra-antennary line is present in all Phreatoicids. There is, however, variation in the degree of development of the lateral lobes. The marginal line (?) is distinct in most cases at least in the sub-ocular region, and its vertical arm is also discernible. In *Phreatoicopsis terricola* this line appears to continue backwards upto the posterior margin of the head.

The genal groove is present in most cases as a short crescentic structure in the genal region. In some cases the posterior arm of the genal groove is confluent with the lower end of occipital groove, and in front it extends as far forwards as the anterior end of mandibular hinge.

The occipital groove is conspicuous on sides only in most species. In some species it extends below to the ventro-lateral border of the head, but generally it ends in the middle of the ventral surface. In *Onchotelson brevicaudatus* (Smith), the occipital groove is complete dorsally, delimiting a well-defined maxillipedal segment behind. In *Phreatoicopsis terricola* (Spencer and Hall) the occipital groove appears to be absent.

SUMMARY

The head, maxillo-sternal framework and endophragmal system of *Nichollsia kashiense* Chopra and Tiwari, are described and compared with those of other Isopods, especially *Ligia oceanica* Linn.

The supra-antennal line is well developed and produced on each side into a triangular projection. Clypeus is assymmetrical and distinct from the frontal lamina. The occipital groove is incomplete and genal fossa is wanting. The presence of an incomplete maxillary sternite is an interesting feature of the maxillary somite. The tergal alæ are very vestigeal and the alar process and infero-lateral pterygoid process are wanting in the sternal alæ.

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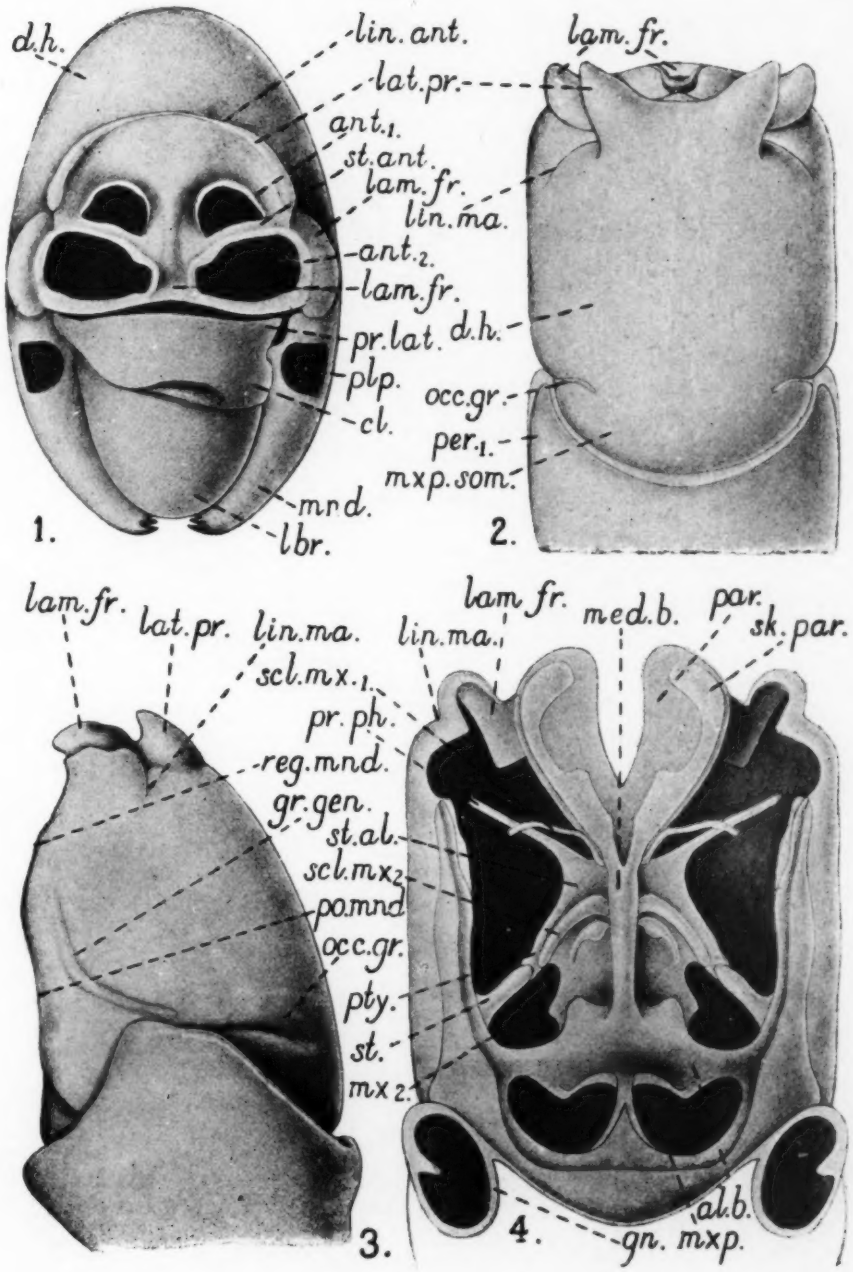
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Explanation of Abbreviations

al. b. .. alar bar
ant. 1 .. antennulary socket
ant. 2 .. antennary socket
cl. .. clypeus
dh. .. dorsal surface of head
gn. .. articular surface of gnathopod
gr. gen. .. genal groove
lam. fr. .. frontal lamina
lat. pr. .. lateral process of the supra antennary line
lbr. .. labrum
lin. ant. .. supra antennary line
lin. ma. .. marginal line
med. b. .. median bar
mnd. .. mandible
mx. 2 .. articular socket of maxilla
mxp. .. articular socket of maxilliped
mxp. som. .. maxilliped somite
occ. gr. .. occipital groove
par. .. paragnath
per. 1 .. antero-ventral expansion of first peraeon segment
plp. .. socket of mandibular palp
po. mnd. .. post-mandibular region of head
pr. ph. .. pharyngeal process
pr. lat. .. lateral process of clypeus
pty. .. maxillo-pterygoid process
scl. mx. 1 maxillulary sclerite
scl. mx. 2 maxillary sclerite
sk. par. .. skeleton of paragnath
st. .. sternite of maxilla
st. al. .. sternal alæ
st.ant. .. portion of the frontal lamina between the sockets of antennule and antenna

Explanation of Plate V

Head of *Nichollsia kashiense* Chopra and Tiwari

Fig. 1. Front view of the head of *N. kashiense* after removal of the antennules and antennae (×54).

Fig. 2. Dorsal view of the same (×54).

Fig. 3. Lateral view of the same (×50).

Fig. 4. Ventral view of the head of *N. kashiense* to show maxillo-sternal framework and endophragmal system. (The oral appendages and soft parts have been removed) (×65).

THE FOOD OF SOME YOUNG FISHES FROM BOMBAY*

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Introduction

A study of the food of young fishes from the Bombay waters was made between June 1945 and June 1947, by the periodic examination of the stomach contents of a number of larval, post-larval and young fishes, belonging to *Clupeidæ*, *Polynemidæ*, *Mugilidæ*, *Gadidæ*, *Percidæ*, *Carangidæ*, *Squamipinnes* and *Sciænidæ*. Observations have also been extended to adults of *Bregmaceros macclellandi*, *Ambassis commersoni*, *Apogon bandanensis* and *Equula insidiatrix*. The analysis of the stomach contents and the percentages of various organisms constituting the food of the different species along with the feeding habits at various stages were noted. The entire work was divided into two parts, of which the first part dealing with "The food of some young Clupeids"[1] had already been published. The present paper deals with the food of 2,188 specimens belonging to the remaining seven families mentioned above. A resumé of the work on the food of fishes, the places of collection of material, the methods adopted and the bibliography having been incorporated in the first part are omitted here.

In the present account, specimens ranging from 1–25 mm. are placed in stage I, those between 25–50 mm. in stage II, between 50–75 mm. in stage III and those 75 mm. and above upto 100 mm. in stage IV. The calendar year is divided into four seasons, namely, the rainy season—June to September, the dry season—October to November, the winter season—December to February and the summer season—March to June. The nomenclature adopted in this paper is according to Day (1889).

Family: Polynemidæ

The larval and post-larval forms of *Polynemus tetradactylus* and *P. heptadactylus*, popularly known as "Rawas" and "Dadha" respectively

* Published with the kind permission of the Chief Research Officer, Central Marine Fisheries Research Station, Mandapam Camp.

[1] Bapat, S. V., and Bal, D. V., "The food of some young Clupeids," *Proc. Ind. Acad. Sci.*, 1950, **32 B**, 39–58.

abound in the waters around Bombay. The former, attaining a length of 4–5 feet is an important commercial food fish highly esteemed as a table fish. The latter grows to a size of 8–12 inches and is mainly consumed by the poor. The fishing is done generally by bag nets and hooks and lines and the fish are landed in large quantities at Sassoon docks, Danda, Versova and other important fishing centres around Bombay. *P. tetradactylus* is also taken in fairly large numbers by the deep sea fishing vessels in the trawl nets.

Polynemus tetradactylus (Shaw.)

220 young forms of *P. tetradactylus* were examined of which 191 were from plankton collections at Versova, Chowpati, Apollo Bunder and Sassoon docks and the remaining from the fishermen's catches at Mahim. 102 of them were taken in the rainy, 54 in dry, 28 in winter and 36 in the summer seasons. A stage by stage analysis of the stomach contents is given in the following table.

Number examined and percentage of food taken by stages I to IV

Stage of fish ..	I	II	III	IV
Total No. of fish examined ..	187	26	2	5
No. of fish with digested or no food ..	79	8	..	1
Items of food taken ..	%	%	%	%
Prawn larvæ ..	65·74	61·12	..	..
Copepods ..	29·62	27·77	..	..
Zoea ..	2·77	..	..	..
Polychætes ..	..	11·11	100·00	75·00
Squilla larvæ ..	..	..	..	25·00
Amphipods ..	0·92	..	..	..
Sagittæ ..	0·92	..	..	..

It is evident from the above table that prawn larvæ and copepods constitute the main food of the young forms in stages I and II. It appears that the more advanced forms in stages III and IV take to polycheates and *Squilla* larvæ. This has to be substantiated with more material. The polychætes were mostly taken during the rainy season.

Polynemus heptadactylus Cuv. and Val.

A total number of 206 specimens ranging from 26–100 mm. were collected from the fishermen's catches at Versova, Danda and Sassoon docks. 34 of them were obtained in rainy, 31 in dry, 86 in winter and 55 in the summer seasons. Their stomach contents in the different stages, excepting the first, are as under;—

Number examined and percentage of food taken by stages II to IV

Stage of fish ..	II	III	IV
Total No. of fish examined ..	21	141	44
No. of fish with digested or no food	8	47	12
Items of food taken ..	%	%	%
Prawn larvæ ..	84·62	57·44	50·00
Fish food ..	..	10·63	12·50
Copepods ..	..	8·51	6·25
Polychætes ..	..	5·31	12·50
Gammarus ..	7·69	2·12	..
Other Amphipods ..	7·69	4·25	..
Cypris ..	..	4·25	3·12
Crustacea remains ..	..	7·44	15·63

It can be seen from the above table, that prawns (*Acetes indicus* and *Acetes* sp.) form the major item of food of *P. heptadactylus* in all the three stages. In the third and fourth stages, the prawn diet is supplemented by fish food consisting of *Otolithus argenteus* and *Bregmaceros macclellandi*, copepods and polychætes. Amphipods and *Cypris* are also taken in smaller percentages.

Chacko (1949)[1] has recorded that *P. tetradactylus* measuring 12–18 cm. feed on prawns belonging to *Penæus* sp. and *Acetes* sp. and *P. heptadactylus* on *Penæus* sp., *Stolephorus* sp. and *Sardinella gibbosa*.

Family: MUGILIDÆ

Mugil dussumieri, *M. troschelli* and *M. parsia* were the three species belonging to this family found in our collections. The first two were obtained exclusively from plankton samples and the last species from the fishermen's catches. *M. troschelli* occurred mostly during the rainy and summer seasons, whereas *M. parsia* practically throughout the year. Specimens of *M. dussumieri* were taken in smaller numbers during the rainy and winter seasons. The stomach of these species is muscular and gizzard-like.

The various species of this family, ranging from 6 to 8 inches in length, are caught in good numbers at Mahim and Versova and are highly esteemed as food when fresh. They are locally known as ' Boi '.

A few specimens from the plankton samples were successfully reared in the laboratory aquaria on fish meal, earthworms and polychætes.

[1] Chacko, P. I. Food and feeding habits of the fishes of the Gulf of Manar. *Proc. Ind. Acad. Sci.*, 1949, **29 B**, 83-97.

Mugil dussumieri Cuv. & Val.

Only 9 post-larval forms ranging from 14–24·5 mm. were obtained, 2 in rainy and 7 in the winter season. Of these 8 were taken from Apollo Bunder and one in Mahim plankton samples.

An examination of their stomach contents revealed copepods in seven specimens from Apollo Bunder and foraminifera and sand grains in the remaining two.

Mugil troschelli Bleeker

38 young forms, measuring from 15–24 mm., were taken from plankton samples at Versova, Mahim, Apollo Bunder and Choupati. 18 of them were obtained in the rainy and the remaining 20 in the summer season.

On examining their stomachs, copepods were found in 16 (69·56%) and diatoms in 7 (30·44%) which evidently shows that they form the main food of the smaller forms. Chacko (1949) has reported that bigger forms 100–350 mm. in length, are mainly plankton feeders, occasionally browsing at the bottom and on the weeds.

Mugil parsia Ham. & Buch.

All the 49 specimens of this species were taken from the fishermen's catches at Mahim, 34 in the rainy, 3 in dry and 12 in the winter seasons. An analysis of their stomach contents was as below:—

Number examined and percentage of food taken by stages I and II

Stage of fish ..	I	II
Total No. of fish examined ..	2	47
No. of fish with digested or no food	1	29
Items of food taken ..	%	%
Copepods ..	100·0	55·55
Diatoms ..	..	11·11
Muddy remains ..	..	11·11
Prawn larvæ ..	..	5·56
Crustacea remains ..	..	16·67

From the above figures it appears that copepods constitute the main food of this species and is only supplemented by diatoms and the organic matter taken along with the mud.

Family: GADIDÆ

Bregmaceros maccelellandi Thomps.

Bregmaceros macclellandi, locally known as 'Tengali', are very common in Bombay waters and generally form the food of the poor. They are taken

in large quantities in the bag net along with other miscellaneous fish at Versova, Danda and Sassoon docks and specimens ranging from 26–100 mm. are available for study throughout the year. According to Day (1889) the species attains a size of 125 mm., but such large sizes are not very common.

It appears that this fish has a prolonged breeding season judging from the mature ova which have been observed for a major part of the year. Its post-larvæ, 8–15 mm. in length, have been taken in plankton samples at the fishing site off Danda, about 5–8 miles away from the shore, indicating that it is an off-shore breeder.

283 specimens were examined for their stomach contents and the details of the findings are given in the following table:

Number examined and percentage of food taken by stages II to IV

Stage of fish ..	II	III	IV
Total No. of fish examined ..	97	164	22
No. of fish with digested or no food	60	89	11
Items of food taken ..	%	%	%
Prawn larvæ ..	40·54	84·00	81·82
Copepods ..	27·02	4·00	..
Crustacea remains ..	32·43	10·66	18·18
Algæ ..	..	1·33	..

It is evident from the above table that prawn larvæ and copepods constitute the main food of *Bregmaceros macclellandi*. It is further seen that the percentage of prawns goes on increasing and that of copepods decreasing as the fish grows in size. Algæ constitute a rare inclusion in the dietary of this fish.

It is of interest to note that this fish forms one of the important items of food of the popularly known " Bombay duck ", *Harpodon nehereus*.

Family: PERCIDÆ

This family is represented in our collections by four genera and five species, namely, *Serranus diacanthus*, *Ambassis commersoni*, *Apogon wassinki*, *A. bandanensis* and *Therapon jarbua*.

The post-larvæ of *S. diacanthus* belonging to the first and second stages are common in plankton collections and can be easily identified by the characteristic six to seven vertical bands on their bodies. The continuous occurrence of the post-larval forms indicates the existence of a prolonged breeding season. The adults usually attain a length of about 18 inches and are known for their highly edible qualities.

Specimens of *Ambassis commersoni* are common in the fishermen's catches during the summer months. They are small size fishes rarely exceeding 7-8 cm. in length and are generally consumed fresh by the poor people. It was observed that the gonads of a majority of the specimens measuring from 51–72 mm. were found to be in a mature state during the summer season which was also the peak period of their occurrence at the Mahim creek. Hence the summer season appears to be the spawning season and in all probability the fish may be migrating to the creek waters for breeding purposes.

The genus *Apogon* is represented by two species, *viz.*, *A. bandanensis* and *A. wassinki*. The former were exclusively taken from the fishermen's catches and the latter from plankton samples. They also attain a size of 7–8 cm. and are of little importance to the commercial fishery. The third stage of *A. bandanensis* was taken in large numbers during the summer season and their ovaries were noticed to be in an advanced stage of development. The post-larval forms of *A. wassinki* were taken almost throughout the year, though in smaller numbers, indicating the probability of a prolonged breeding season.

Young forms of *Therapon jarbua* were taken both from plankton samples and fisherman's catches regularly in all the seasons. Their adults attain a length of 7–8 inches and are much less used as food.

The food and feeding habits of the above five species are discussed below in detail separately.

Serranus diacanthus Cuv. & Val.

248 Specimens varying between 12–70 mm. were examined, 150 in rainy, 24 in dry, 41 in winter and 33 in the summer seasons. The results of the examination of their stomach contents are given below:

Number examined and percentage of food taken by stages I to III

Stage of fish ..	I	II	III
Total No. of fish examined ..	137	109	2
No. of fish with digested or no food ..	35	43	..
Items of food taken ..	%	%	%
Copepods ..	56·86	33·33	..
Prawn larvæ ..	29·41	19·61	..
Gammarus ..	0·98	19·69	50·00
Other Amphipods ..	9·80	16·16	50·00
Polychætes ..	..	3·03	..
Bivalves ..	..	3·03	..
Zoea ..	..	1·51	..
Crab remains ..	..	1·51	..
Megalopa ..	0·98	..	..
Crustacea remains ..	1·96	1·51	..

The young forms of this fish during the first and second stages appear to feed mainly on copepods, prawns and amphipods. It is of interest that the percentages of copepods and prawns decrease and those of amphipods increase during the second stage. Prawn larvæ and copepods were consumed more during the rainy season.

Ambassis commersoni Cuv. & Val.

130 Specimens of *A. commersoni*, 117 in summer, 8 in winter and 5 in the rainy season were collected from Mahim creek during the period under report. Their stomachs were found to contain the following:

Number examined and percentage of food taken by stages II to III

Stage of fish ..	II	III
Total No. of fish examined ..	62	68
No. of fish with digested or no food ..	26	24
Items of food taken ..	%	%
Polychætes ..	25·00	63·63
Copepods ..	25·00	..
Prawn larvæ ..	11·11	18·18
Gastropods ..	13·89	6·81
Gammarus ..	11·11	6·81
Other Amphipods ..	..	4·54
Crustacea remains ..	13·89	..

It appears from the above that the main food of *A. commersoni* consists of polychætes, prawn larvæ and copepods, the last being taken only in the second stage. The percentage of polychætes and prawns is on the increase as the fish grows in size. The organisms supplementing the above food are *Gammarus*, gastropods and amphipods.

Apogon bandanensis Bleeker

78 Specimens of this species were collected from the fishermen's catches, 53 from Versova and 25 from Sassoon docks in the summer season. A detailed report of their stomach contents according to different stages is given above.

It is seen from the above that prawns and fishes form the main food of *A. bandanensis* in the early stages supplemented by amphipods and *Cypris*. The fish food comprised of *Bregmaceros macclellandi*, *Engraulis commersonianus* and *Clupea* sp.

Number examined and percentage of food taken by stages II to III

Stage of fish ..	II	III
Total No. of fish examined ..	55	23
No. of fish with digested or no food ..	17	3
Items of food taken ..	%	%
Prawns ..	31·57	50·00
Fish food ..	21·05	30·00
Gammarus .	10·52	..
Other Amphipods ..	15·78	10·00
Cypris ..	15·78	5·00
Squilla larvæ ..	..	5·00
Crustacea remains ..	5·26	..

Apogon wassinki Bleeker

A total number of 99 specimens of *A. wassinki* ranging from 4·5–17 mm. in length were examined, 13 in rainy, 20 in dry, 56 in winter and 10 in the summer seasons. 92 of them were taken in Apollo Bunder and 7 in Choupati plankton samples. An examination of their stomachs revealed copepods in 20, diatoms in 7, prawn larvæ in 1 and crustacean remains in 5. The remaining 66 had either digested food or empty stomachs.

It has been observed that the post-larval forms fed mostly on copepods almost throughout the year, diatoms being taken mainly during the winter season.

Therapon jarbua (Forsk.)

78 Specimens of *T. jarbua* were examined, of which 31 were from the fishermen's catches and the remaining from plankton samples. 17 of them were obtained in the rainy, 14 in dry, 33 in winter and 14 in the summer season.

Number examined and percentage of food taken by stages I to III

Stage of fish ..	I	II	III
Total No. of fish examined ..	47	24	7
No. of fish with digested or no food ..	23	12	2
Items of food taken ..	%	%	%
Copepods ..	62·50	8·33	..
Prawn larvæ ..	20·83	16·66	20·00
Muddy remains ..	16·66	25·00	60·00
Gammarus ..	..	33·33	..
Polychætes ..	..	8·33	20·00
Fish remains ..	..	8·33	..

The younger forms of *T. jarbua* appear to feed mainly on copepods while the more advanced ones resort to bottom feeding, when mud along with a small percentage of prawn larvæ, *Gammarus* and polychætes is taken.

The adults of this species have been described as omnivorus feeders by Chacko (1949)[1] and insectivorous by Job (1940).[2]

Family: CARANGIDÆ

The family Carangidæ is represented in our collection by four species belonging to two genera, namely, *Chorinemus toloo*, *Equula fasciata*, *E. insidiatrix* and *E. ruconius*. *E. fasciata* occurred exclusively in plankton collections and the other three species from the fishermen's catch only.

The adults of *C. toloo* reach a length of about 18 inches while those of *Equula*, popularly known as ' Silver Bellies ' to 4–5 inches. *C. toloo* and *E. fasciata* occurred in large numbers during the rainy season. Specimens of *E. insidiatrix* 26–50 mm. in length were in abundance during the winter and the more advanced stages in the summer season. *E. ruconius* were found in the winter season only.

Chorinemus toloo Cuv. & Val.

In all 65 specimens were collected from the Mahim creek, 40 in rainy, 4 in dry, 7 in winter and 14 in the summer season. A study of their stomach contents during the second and third stages can be summarised as below:

Number examined and percentage of food taken by stages II to III

State of fish ..	II	III
Total No. of fish examined ..	55	10
No. of fish with digested or no food ..	26	3
Items of food taken ..	%	%
Prawn larvæ ..	68·96	71·42
Gammarus ..	13·79	14·28
Copepods ..	6·89	..
Crustacea remains ..	10·34	14·28

It appears from the above data that post-larval and immature forms of *C. toloo* mainly subsist on prawn larvæ and *Gammarus*, copepods being taken only by the forms belonging to the second stage.

[1] Chacko, P. I. Food and feeding habits of the fishes of the Gulf of Manar. *Proc. Ind. Acad. Sci.*, 1949, **29 B**, 83–97.

[2] Job, T. J. Nutrition of Madras Perches. *Rec. Indian Mus.*, 1940 **42**, 286–364.

Equula fasciata (Lacep)

In all, 45 specimens measuring 9–18 mm. were taken in plankton samples, 43 from Apollo Bunder and only 2 from Choupati. 41 of them were obtained in rainy, 3 in dry and a single specimen in the summer season. An examination of their stomach contents revealed copepods in 21, gastropods in 1 and the remaining 23 had either digested food or empty stomachs.

From the data available it can only be inferred that copepods form the main food of the post-larval forms of *E. fasciata.*

Equula insidiatrix (Bloch)

A total number of 127 specimens of this species were examined, of which 68 were obtained in winter and 59 in the summer season. Almost all of them were taken from the fishermen's catches at Mahim creek, excepting 12 from Sassoon docks. An examination of their stomach contents according to different stages showed as under:

Number examined and percentage of food taken by stages II to III

Stage of fish ..	II	III
Total No. of fish examined ..	85	42
No. of fish with digested or no food ..	48	22
Items of food taken ..	%	%
Copepods ..	35·13	15·00
Polychætes ..	35·13	60·00
Gastropods ..	10·81	..
Prawns ..	2·70	5·00
Crustacea remains ..	16·21	20·00

It will be seen from the above table, that polychætes and copepods formed the main food of *E. insidiatrix.* The former were mostly taken in summer and the latter in winter. Gastropods were consumed only by specimens of the second stage, during winter months.

Equula ruconius (Ham. & Buch.)

Only ten specimens of this species ranging from 36–38 mm. were obtained from the fishermen's nets during the winter season from Mahim creek and Sassoon docks. On examining, 7 of them were found to contain polychætes, 1 had crustacea remains and the remaining 2 had no food.

This tends to show that *E. ruconius* like *E. insidiatrix* takes a very high percentage of polychætes.

Family: SQUAMIPINNES

Scatophagus argus (Bloch.)

Scatophagus argus is the single species of this family recorded in our collections from plankton as well as fishermen's catches. It is easily detected by its characteristic flattened body and a large number of bright dark green spots on the back. It is a rare fish in Bombay waters and is said to attain a foot in length.

In all 16 specimens varying between 31-79 mm. in length were examined, 2 in dry, 5 in winter and 9 in the summer season. 5 of them were taken from plankton samples collected off Apollo Bunder and the remaining from the fishermen's catches at Mahim creek. An examination of their stomach contents revealed green algæ in 9, prawn larvæ in 1 and the remaining 6 had either digested food or empty stomachs. This leads us to believe that *S. argus* is a herbivorus feeder, and this view is further supported by the presence of a very long alimentary canal usually found in herbivorus fishes. In a specimen of 73 mm. long the alimentary canal was 196 mm., nearly three times the length of the fish itself.

Family: SCIÆNIDÆ

This family was represented in our collection by five species, four belonging to the genus *Sciæna* and one to *Otolithus*. Of the five species, *Otolithus argenteus* and *Sciæna semilustosa* occurred practically in all the seasons. *S. glauca* and *S. miles* were found in good numbers in summer, though a few specimens of the former in winter and of the latter in the rainy season were also collected. *S. albida* was rare and was obtained only once in August 1945. A total number of 491 young forms of these species were collected from the fishermen's catches from Sassoon docks and Versova. They were conspicuously absent in the plankton samples.

Adult fishes measuring 3–5 feet in length, popularly known as 'Ghol' are hauled by fishermen in good numbers at Sassoon docks, Versova, Danda and other fishing villages around Bombay, almost throughout the year. They also form an important group of the catches of trawlers operating off Bombay. They possess highly edible qualities and have a good market at Bombay. The immature forms are used as food by the poorer class of people.

Sciæna miles Cuv. & Val.

A total number of 66 post-larval and immature forms, 56 in summer and 10 in rainy were examined.

Number examined and percentage of food taken by stages II to IV

Stage of fish ..	II	III	IV
Total number of fish examined ..	23	25	18
No. of fish with digested or no food ..	7	7	3
Items of food taken ..	%	%	%
Prawn larvæ ..	93·75	66·66	40·00
Copepods ..	6·25	..	..
Squilla larvæ ..	..	16·66	6·66
Cypris ..	..	5·55	6·66
Fish food ..	..	..	40·00
Amphipods ..	..	..	6·66
Gammarus ..	..	5·55	..
Crustacea remains ..	..	5·55	..

It may be seen from the above table that prawn larvæ formed the major item of food of the young forms of *S. miles*. The grown-up fish take in addition fish food comprising *Bregmaceros macclellandi*. This was supplemented to some extent by *Squilla* larvæ, *Cypris* and *Gammarus*.

Sciæna albida (Cuv. & Val.)

Only five specimens of this fish measuring 60–90 mm. were collected on 10th August 1945, at Sassoon docks. An examination of their stomachs revealed prawn larvæ belonging to the genus *Acetes* in three, and the other two were empty.

Sciæna semiluctosa (Cuv. & Val.)

A total number of 109 specimens, 11 in rainy, 23 in dry, 35 in winter and 40 in the summer season were examined for their stomach contents and an analysis of the same is given below:

Number examined and percentage of food taken by stages II to IV

Stage of fish ..	II	III	IV
Total No. of fish examined ..	38	69	2
No. of fish with digested or no food ..	11	20	..
Items of food taken ..	%	%	%
Prawn larvæ ..	59·25	59·18	50·00
Cypris ..	18·52	..	..
Fish food ..	3·70	26·53	..
Copepods ..	7·41	4·08	..
Polychætes ..	3·70	..	..
Amphipods ..	..	2·04	..
Crustacea remains ..	7·41	8·16	50·00

From the figures cited above, it can be inferred that prawn larvæ are again the main item of food. The other planktonic forms taken are *Cypris*, copepods, polychætes and amphipods. *Bregmaceros macclellandi*, *Coilia dussumieri* and some Clupeids also formed a considerable part of the food of the specimens of the third stage in particular. *Sciæna semiluctosa* appears to be a voracious feeder as the stomachs of most of them were usually gorged with food material.

Sciæna glauca Day

Young forms of *S. glauca* 99 in number were collected from Sassoon docks and Versova, 6 in winter and 93 in the summer season. The adults of this species popularly known as ' Dhoma ' attain a length of about 2–3 feet and are common at Bombay.

Number examined and percentage of food taken by stages II to IV

Stage of fish ..	II	III	IV
Total No. of fish examined ..	13	46	40
No. of fish with digested or no food	3	18	8
Items of food taken ..	%	%	%
Prawn larvæ ..	80·00	67·85	56·25
Fish food ..	..	7·14	25·00
Polychætes ..	10·00	..	..
Squilla larvæ ..	..	7·14	..
Crab remains ..	..	3·57	..
Cypris ..	..	..	3·12
Muddy remains ..	..	..	3·12
Crustacea remains ..	10·00	14·28	12·50

It can be seen from the above data that prawn larvæ also form the main food of *S. glauca* in the second, third and fourth stages. The fish food mainly consisting of *Bregmaceros macclellandi* and *Engraulis commersonianus* is taken in increasing proportions by the advanced forms. The other organisms consumed in smaller percentages are polychætes, *Squilla* larvæ and *Cypris*.

The tendency to feed on refuse at the bottom is not uncommon as observed from the presence of mud along with lobster and crab remains. It appears to be a voracious feeder as the stomachs of most of the specimens were found packed with food materials.

Otolithus argenteus Cuv. & Val.

The post-larval forms of *O. argenteus* are very common in Bombay waters almost throughout the year. In all 208 specimens were collected

from the fishermen's catches at Versova and Sassoon docks, 93 in rainy, 46 in dry, 28 in winter and 41 in the summer season. An analysis of their stomach contents is given in the table below:

Number examined and percentage of food taken by stages I to IV

Stage of fish ..	I	II	III	IV
Total No. of fish examined ..	4	102	80	22
No. of fish with digested or no food ..	.	39	26	4
Items of food taken ..	%	%	%	%
Prawn larvæ ..	25·00	73·01	88·88	50·00
Gammarus ..	25·00	1·58	..	..
Fish food ..	..	6·34	1·85	38·88
Other Amphipods ..	..	9·53	1·85	..
Copepods ..	..	4·76	1·85	..
Squilla larvæ ..	..	1·58	..	..
Polychætes ..	..	..	1·85	..
Crab remains ..	..	..	..	5·55
Sand and gastropods ..	50·00	..	..	..
Crustasea remains ..	..	3·17	3·70	5·55

A close scrutiny of the above figures will show that prawns form the main food of *Otolithus argenteus* like that of *Sciæna* sp. during all the four stages described here. It appears to be a surface plankton feeder. In the more advanced forms it appears that the fish food is taken in increasing percentages until finally it forms the major item of the food of the adult. The fish food mainly consisted of *Bregmaceros macclellandi* and *Pellona* sp.

Summary

In the present investigation extending over a period of two years from June 1945 to June 1947, the stomach contents of 2,188 young fishes belonging to 21 species were examined for determining their food and feeding habits.

1. The young forms of almost all the species are surface plankton feeders, and are carnivorous, except *Scatophagus argus* which feeds mainly on algæ.

2. Planktonic prawn larvæ mostly belonging to the genus *Acetes* formed the main food of the young forms of a number of species mentioned above, whereas the grown-up ones seem to prefer mostly fish diet consisting of *Bregmaceros macclellandi*, *Engraulis commersonianus*, *Otolithus argenteus*, Clupeids, etc.

3. *Equula insidiatrix* and *E. ruconius* seem to have a special liking for polychætes, whereas copepods formed the main food of the young forms of *E. fasciata* during the first stage.

4. Diatoms in fairly high percentages were taken by *Mugil troschelli* and *M. parsia*, though copepods formed their main item of food.

5. Amongst the Percidæ, the amphipods formed an important item of food in addition to prawn larvæ and copepods. *Ambassis commersoni*, however, has a greater preference to polychæte food.

6. The younger forms of all the Sciænids take prawns as their main food, and the percentage of their fish food goes on slowly increasing as they grow in size.

EXPERIMENTS ON THE ACCLIMATISATION OF SALT WATER FISH SEED TO FRESHWATER*

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Introduction

It is now generally accepted that the freshwater fauna of the present day have been largely derived from ancient marine animals. Unlike the temperate regions, the number of marine animals that have migrated into brackish water and freshwater habitats is very large in the tropics. The meeting places of large volumes of freshwater and salt water, like the estuaries of large rivers, back-waters, etc., are the regions where this natural acclimatisation is daily taking place. Panikkar and Aiyar (1937) in a noteworthy contribution on the brackish water fauna of Madras observe: "We find in every tropical back-water, tidal creek or estuary, an active and aggressive attempt on the part of many marine species to secure a permanent foothold either in the semi-aquatic mudflats and mangroove swamps or in the salt marshes with peculiar environmental conditions of fluctuating salinity, temperature and hydrogen ion concentration." The above observation is no less true in the case of fishes, and in India, with the extensive coast line and numerous estuaries of

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rivers and streams, the number of species of marine fish that are capable of natural acclimatisation to lower concentrations of salinity and even to freshwater is large. The capacity to successfully adjust to the fluctuating conditions, however, varies with the species. While species like *Chanos chanos*, *Elops saurus*, *Megalops cyprinoides*, *Lates calcarifer*, etc., grow quickly in the freshwater environment, they have to migrate to the sea (salt water) for the normal ripening of their gonads and breeding. Several species of mullets (*Mugil* spp.) fatten quickly in freshwater and some have even been found to have the gonads in advanced stages of ripeness, even though they are not definitely known to breed in freshwater; *M. corsula* being the only known exception. *Hilsa* is a well-known example of a marine species migrating to freshwater for breeding purposes; but it is capable of thriving in freshwater also. Extreme adaptation is exhibited by the pearl-spot, *Etroplus suratensis*, the orange-chromide, *Etroplus maculatus* and the goby, *Glossogobius giuris*, all of which could live and propagate in both salt and fresh water. The relative, natural capacity of the different species to adjust to the fluctuating environmental conditions is bound to reflect in their resistance to sudden changes during experimental acclimatisation.

In Madras, the difficulties in securing enough seed of the economically important carps for stocking inland waters, and the availability of several valuable centres for collection of salt water fish seed, have naturally stimulated attempts at acclimatisation of selected species of the latter for enriching the inland water crop. Job and Chacko (1947) have given a brief account of the important species of saltwater fish that are capable of easy acclimatisation to freshwater and which are being employed for stocking inland waters in Madras. Devanesen and Chacko (1943) found the marine mullets *M. troschelii* and *M. waigiensis* capable of successful acclimatisation to freshwater in about 3 days. A protracted period of 12 days was found necessary for *M. seheli* for successful acclimatisation to freshwater (Venkataraman, 1944). Ranganathan and Ganapati (1949) have found that chanos fry (1″ to 6″) were hardy and capable of withstanding even direct transfer from seawater to freshwater.

The successful culture of salt water fish in freshwater depends mainly on the speed with which they could be acclimatised to the new environment, without any mortality being caused during the process. Since processes of osmoregulation are involved in the transition from salt water to freshwater and since the osmoregulatory powers of the different species of fish seem to vary during different stages of their life-history, it is of primary importance to ascertain, in respect of each species, the stage at which they could most

successfully withstand the variations in salinity and other environmental factors, without deleterious effects. Knowledge of the acclimatisable stage of the different species is of considerable economic significance as it would prevent wrong selection of stage or size and is likely to yield better results during experimentation and after.

Experiments on the acclimatisation of salt water fish seed to freshwater have been carried out, during the last five years, at the Freshwater Biological Research Station, Madras, with a view to evolving satisfactory methods for the different species and standardising the same, for field conditions and requirements. Details of these experiments are furnished in this report.

Experiment I

Fry and fingerlings of *Mugil* spp., *E. suratensis*, *M. cyprinoides*, *E. saurus*, *Gerres filamentosus*, *Scatophagus argus* and occasionally *L. calcarifer* are collected annually from the Adyar backwaters for stocking purposes. The season usually extends from October to February.

On 28–11–1945, a small experimental consignment of about 150 fry (0·6″ to 0·75″ long) of *Mugil* spp. was taken from Adyar to Chetput in an earthen pot. Salinity of the water was only 15·00‰. There was heavy mortality during transport and by about 3 P.M. even the remaining ones were weak. By setting up a siphon arrangement, fresh brackish water was allowed to drip slowly into the container, and this had beneficial effect on the fry. There was no mortality till 7 P.M., when some freshwater was added and the salinity was brought down to 12·69‰. By next morning 5 specimens had died and another 5 were weak and swimming near the surface. At 11 A.M. more freshwater was added and the salinity was lowered to 11·44‰. One specimen died at 2 P.M. At 5–55 P.M. salinity was stepped down to 5·11‰ and the fry were left overnight in this medium. There was no casualty during the night and by 9–45 A.M. the next morning, the salinity was further lowered to 2·64‰. The fry behaved quite normally, though appeared weak. More freshwater was added by 6 P.M. and the salinity dropped to 1·58‰. By next morning, the fry looked very weak and emaciated. Some live plankton collected from the pond was introduced into the aquarium and the fry immediately became noticeably active and were seen feeding on the plankton. More plankton was added and the fry were again left overnight in this sweet water and on the 4th day they were successfully transferred to freshwater. There was no mortality.

Remarks.—Only a limited number of fry were used in this experiment. The dilution of the medium was spread over a period of about 90 hours only.

The condition of fry during the third day was very poor and introduction of live plankton as food in the aquarium had definite, beneficial effect and mortality during the subsequent stages was negligible. This indicated the possibility that in a prolonged course of acclimatisation the young fry may be better equipped to adjust to hydrobiological changes provided they are fed suitably during the transitional phases.

EXPERIMENT II

A bigger consignment of about 600 fry, $\frac{1}{2}''$ to $1\frac{1}{2}''$ long, of *Mugil* spp., was taken from Adyar to Chetput on 3–12–1945. The bigger fry were provisionally identified as *M. cephalus* while the smaller ones, on rearing in the pond, were identified as *M. seheli*. The fry were collected from the shallow expanses, by means of miniature drag nets of fine mesh. In spite of the presence of shoals of fry, collection was comparatively difficult; the fry when frightened, generally take shelter in the small shallow depressions in the uneven muddy bottom. They remain quiet in these pits till the net is dragged over, when they escape. From the net the fry were transferred to a bucket of water by means of a small hand net. After about 10 minutes they were transferred to a second bucket of brackish water and thence to the tin carrier containing clean brackish water. They were transported to the Chetput Farm within 3 hours after collection. Mortality during transport was negligible. Salinity of water at the collection spot was 15·00‰. The following experiments were tried at the Farm:

(i) Direct transfer of fry and fingerlings from brackish water to freshwater was tried as follows:

TABLE I

Aquarium No.	No. of fry introduced	Average Size	Casualty		Remarks
			No.	Duration	
1	12	$1\frac{1}{2}''$	7	18 hrs.	Of the remaining, 2 weak; 3 normal
2	12	$1''$	7	18 hrs.	Remaining 5 normal
3	12	$\frac{1}{2}''-\frac{3}{4}''$	9	18 hrs.	Remaining 3 normal

While the mortality ranged from 58 to 75% it was evident that at least some of the fry could tolerate even direct transfer from brackish water to freshwater. Of the three sizes of fry taken, 1″ long fry gave the maximum percentage of survival (42%).

(ii) 550 specimens, ½″ to 1″ long, were released in a large shallow aquarium containing brackish water. A tin carrier of freshwater from the pond was placed at a higher level and by siphon arrangement, was made to drip in slowly into the aquarium. Some live plankton was also introduced into the aquarium.

During the first 24 hours, 168 specimens died and another 15 were extremely weak and were removed. The salinity had come down to 12·16‰. It was considered that the continuous though slow dripping in of freshwater will be continuously altering the salinity of water in the aquarium, and might have kept the fry in a very uncomfortable state throughout, without giving them time to adjust themselves to any fixed grade of salinity. This might have accounted for the high mortality and the above arrangement was therefore stopped.

Another 44 specimens died during the next 12 hours.

The salinity was then stepped down to 11·10‰. The general condition of the fry was very weak by this time, and feeding was therefore attempted. Small stones with algal encrustations were taken from a pond and placed in the aquarium. Immediately the fry were seen crowding round these stones and were actively feeding, nibbling at the algal growth. There was no mortality during the night.

On the third day the salinity was brought down to that of freshwater in three stages, *i.e.*, 6·51‰ in the morning, 4·58‰ at about 1 P.M. and freshwater at about 6 P.M. Feeding was continued. There was no mortality during the night. The fish were thus brought to freshwater in the course of about 74 hours. They were kept in freshwater in the aquarium for two more days with regular feeding, but there were no casualties. 323 Fry were successfully acclimatised and released into the pond.

Remarks.—Acclimatisation was completed in a shorter period than in the first experiment. Mortality during the experiment was about 43%. Continued dripping in of freshwater and the resulting slow but continuous change in salinity appear to be positively harmful to the young fry, and the mortality resulted only when this arrangement was working. When this was stopped and arrangements for feeding the fry were made, the mortality was reduced to nil. That feeding during acclimatisation is beneficial is again illustrated by this experiment.

Experiment III

A small consignment of about 250 fry of *M. seheli* and *Mugil* spp., 0·6″ to 1·5″ long, was transported from Adyar to Chetput on 18-12-1945,

The salinity of water at the collection spot was 27·27‰. The incoming high tide water was responsible for the increased salinity. 45 Specimens, mainly small ones, died during transport.

At the Chetput Farm an attempt was made to step down the salinity of water in different stages as follows:

Aquarium 1.—18 Litres of brackish water of salinity 27·27‰, were poured in and 100 fry were introduced. A few stones with algal encrustations were placed in the aquarium for the fry to feed. 3 hours later (4 P.M.) the salinity was stepped down to 21·35‰ by adding freshwater and the fry were left overnight in the aquarium. There was no mortality. At 8–30 A.M. (16½ hours after) the salinity was again lowered to 16·07‰; 6 hours later the salinity was again stepped down to 10·74‰ and was further lowered to 5·28‰ after a similar duration. By 2–30 A.M. the fry were successfully transferred to freshwater. Mortality during the experiment was only 11.

Aquarium 2.—18 litres of brackish water of salinity 27·27‰ were poured in and 100 fry were introduced. Stones with algal encrustations were placed for feeding. 3 Hours later (4 P.M.) the salinity was lowered to 17·84‰ by the addition of freshwater. By the next morning, 25 specimens had died. At 8–30 A.M. the salinity was again lowered to 8·96‰. By 2–30 P.M. 6 more specimens had died. The remaining fry were then transferred to freshwater and left overnight in the aquarium. 16 Specimens had died during the night making the total number of casualties 47.

Remarks.—In aquarium 1 the experiment was completed in about 34½ hours; while in aquarium 2 the duration of the experiment was only 22½ hours. The change in salinity in each step was about 5·28 parts in aquarium 1 and the mortality during the experiment was only 11%. In aquarium 2 the salinity was lowered more abruptly than in aquarium 1, the difference in salinity between the different steps being 8·96‰. The excessive mortality during this experiment is probably to be attributed to this factor. However, since two factors, *viz.*, duration of the experiment and change in salinity at each step were both variables in the two aquaria, exact comparisons cannot be made.

EXPERIMENT IV

Based on the trends indicated in the above experiments under laboratory conditions, a large-scale field experiment was planned and carried out in February 1947.

0·5″ to 1·0″ long mullet fry (*M. cephalus*, *M. seheli*, *M. speigleri*, etc.) were abundant in the shallow expansive Adyar backwaters, on 10–2–1947,

Tide was low at about 7·30 A.M. and owing to the low level of water the fry were largely confined (mainly in shoals) to the meandering course of the narrow 'Kalvai' (Channel) commencing from the nearby road bridge and extending eastwards to the backwaters. By fixing a small drag net of mosquito curtain cloth across the 'Kalvai', and driving in the shoals of fry, a good number of them could be easily collected. Fry from the net were transferred to a bucket of clean brackish water by means of a silk-hand-net, and later on to the tin carrier. A consignment of 4 tins containing fry and 2 tins with clean brackish water was transported in an open hand cart to Chetput. Water was poured on the tins *en route* so as to keep them cool in the hot sun. The consignment reached Chetput farm by 2 P.M. The physico-chemical conditions of the water at the collection spot and in the tin carriers at the time of commencement of transport and at the destination were determined and are tabulated in Table II.

TABLE II

Conditions of existence of mullet fry at the Adyar backwaters and in the tin carriers during transport to the Chetput Farm on 10–2–1947

(Results expressed in parts per 100,000 unless otherwise stated

No.	Location	Time	Weather	Temp. °C.	Free CO_2	CO_3	HCO_3	pH	D.O. c.c./l.	% Sat.	S. ‰
1	From the Kalvai ..	8-20 A.M.	Bright, sunny	26·6	nil	3·3	15·25	8·4	2·462	41·9	24·83
2	From tin carrier before transport	11 A.M.	,,	31·2	,,	3·6	20·44	8·3	2·111	..	24·83
3	Do. after transport, at Chetput	3 P.M.	,,	30·6	,,	2·7	19·93	8·2	2·99	54·2	24·83

The slight fall in the pH of the water recorded at the destination is attributable to the respiratory activities of the fishes. A slight rise in the dissolved oxygen content is also recorded at the destination, in spite of the presence of fishes in the tins. The continuous jolting during the three-hour period of transport is probably responsible for this increased oxygen content.

The consignment which consisted mainly of mullets with a few specimens of *Oryzias melastigma* and *Acentrogobius* sp. was sorted out at the Chetput Farm and was found in Table III.

Out of 1,369 mullets transported 157 died during transport, representing 11·4%. It is interesting to note that mortality was nil in the miscellaneous species like *Oryzias melastigma* and *Acentrogobius* sp.

TABLE III

Tin No.	Mullets		*Oryzias*		*Acentrogobius*		Total	
	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
1	313	88	4	Nil	Nil	Nil	317	88
2	322	35	26	,,	9	,,	357	35
3	361	29	43	,,	36	,,	442	29
4	216	5	1	,,	3	,,	220	5

At the Chetput Farm, the live fry were sorted out from the dead ones and three experiments were arranged, each for different periods of acclimatisation. In all the experiments the salinity during the different stages of dilution was stepped down to the extent of 8·96. Details of the experiments are as follows:

(i) *Tub No.* 1.– 40 litres of brackish water (24·83‰) were measured out into a large wide-mouthed earthenware tub and 404 mullet fry were introduced. After noting the physico-chemical conditions of the water, the salinity was stepped down by 8·96 by removing the calculated volume of brackish water from the tub and adding requisite volume of freshwater from a pond. The physico-chemical conditions after dilution were noted. Six hours later

TABLE IV

S. No.	Date	Time	Before (A) or after (B) dilution	Temp. (°C)	S. ‰	*Free CO_2	*CO_3	*HCO_3	pH	D.O. c.c./l.	% Sat.	No. of Fry	No. died	% Mortality	Dilution interval Hrs.
1	10-2-47	5-15 P.M.	A	26·3	24·83	Nil	0·45	22·26	8·0	1·527	36·9	404	1	..	..
2	,,	,,	B	27·0	16·07	,,	0·90	22·56	8·0	2·267	55·4	403	..	..	..
3	,,	11·15 P.M.	A	23·9	16·07	,,	0·90	24·40	7·9	1·133	26·3	403	12	3	6
4	,,	,,	B	..	7·04	,,	0·60	24·23	8·0	2·759	..	,,	..	..	..
5	11-2-47	5-15 P.M.	A	23·0	7·04	,,	0·60	26·23	8·0	1·823	41·7	391	12	3	6
6	,,	,,	B	..	0·14	,,	0·90	26·23	8·0	2·759	..	379	.	..	..
7	12-2-47	8 A.M.		..	0·14							,,	18	..	..
											Total		42	10·4	12

* Results expressed in parts per 100,000.

the salinity was again lowered by 8·96, bringing it to 7·04. In the third step, 12 hours after commencement of the experiment the fish were brought to freshwater. Only 24 specimens died during the experiment. In freshwater 18 more specimens died within the first 24 hours; bringing the total percentage of mortality to 10·5.

The physico-chemical conditions of the water during the experiment are given in Table IV.

(ii) *Tub No.* 2.—The total period for acclimatisation of the fry to freshwater was longer, being 16 hours; while, all other conditions were identical to those in Tub No. 1. The salinity was also stepped down by 8·96 at a time, but the duration in each grade was longer than in the first experiment. The data gathered are tabulated below:

TABLE V

S. No.	Date	Time	Before (A) or after (B) dilution	Temp. °C.	S°/₀₀	*Free CO_2	*CO_3	*HCO_3	pH	D.O c.c./l.	% Sat.	No. of fry	No. died	% Mortality	Dilution interval Hrs
1	10-2-47	5-15 P.M.	A	26·3	24·83	Nil	0·45	22·26	8·0	1·527	36·9	404	12	..	..
2	,,	,,	B	27·0	16·07	,,	..	..	..	2·267	..	392	..	..	..
3	11-2-47	1-15 A.M.	A	23·6	16·07	0·184	..	26·23	7·8	1·108	25·6	392	78	..	8
4	,,	,,	B	..	7·04	0·164	..	24·40	7·9	2·462	..	314	..	..	..
5	,,	9-15 A.M.	A	23·9	7·04	0·228	..	27·76	7·8	0·990	22·9	314	41	..	8
6	,,	,,	B	26·1	0·14	Nil	0·30	26·23	8·0	2·659	64·1	273	..	..	..
											Total		137	34	16

* Results expressed in parts per 100,000.

(iii) *Tub No.* 3.—The experiment was carried out under identical conditions as in the two previous ones, but the total period of acclimatisation was 20 hours, the duration in each grade of salinity being 10 hours. The results are given in Table VI.

Remarks.—The three experiments were carried out under identical conditions like volume, depth and surface area of water, number of fish, etc. The hydrological conditions to start with were also more or less identical. The only variable factor was the duration in each grade of salinity (6 hours, 8 hours and 10 hours in tubs 1, 2 and 3 respectively). In tub 1 the fish were brought to freshwater in 12 hours. Mortality during the experiment was low, being only just over 10%. In tubs 2 and 3 the acclimatisation was

TABLE VI

S. No.	Date	Time	Before (A) or after (B) dilution	Temp. °C	S ‰	*Free CO_2	*CO_3	*HCO_3	pH	D.O. c.c./l.	% Sat.	No. of fry.	No. died	% Mortality	Dilution interval Hrs.
1	10-2-47	5-15 P.M.	A	26·3	24·83	Nil	0·45	22·26	8·0	1·527	36·9	404	18	..	..
2	,,	,,	B	..	16·07	,,	..	..	..	2·369	..	386	..	..	..
3	11-2-47	3-15 A.M.	A	23·0	16·07	0·204	..	22·535	7·7	0·523	0·84	,,	43	..	10
4	,,	,,	B	..	7·04	0·196	..	25·315	7·8	2·512	..	343	..	..	..
5	,,	1-15 P.M.	A	26·9	7·04	0·232	..	28·010	7·6	0·486	8·27	,,	34	..	10
6	,,	,,	B	27·5	0·14	..	0·80	24·095	8·1	3·300	81·4	309	..	..	..
7	12-2-47	..	..	..	0·14	..	..	..	..	..	..	..	13	..	..
											Total		90	22·2	20

* Results expressed in parts per 100,000.

completed in 16 and 20 hours, respectively. The mortality was high, being 34 and 22·2% respectively.

There is no doubt that a considerable proportion of the casualties was due to shock sustained and injuries received during collection and transport. The fact that fish were dying in the experimental tubs even before actual commencement of the acclimatisation experiments, *i.e.*, before salinity was lowered, clearly supports this. However, since no control tub with fish in brackish water was maintained the extent of the mortality due to injuries cannot be ascertained. In any case, it is obvious that mortality due to strain during acclimatisation would be appreciably less than what is now recorded.

Since the extent of mortality due to injuries should be considered as equal in all the three tubs, the reason or reasons for the excessive mortality in tubs 2 and 3 has to be sought for elsewhere. A perusal of the physico-chemical data in Tables V and VI will show that in tubs 2 and 3 since the duration in each grade of water was long, the depletion of dissolved oxygen has been very marked, much more than in tub 1 (Table IV) and this might probably account to weaken the general condition of fry. Low oxygen tension, coupled with free carbon-dioxide in the water is inimical to their existence.

EXPERIMENT V

Another consignment of fry and fingerlings of mullets, *Elops saurus*, *Gerres filamentosus*, etc., was transported from Adyar to Chetput on

17–2–1947. The consignment was analysed at the Chetput Fish Farm as follows:

TABLE VII

Tin No.	Mullets				*E. saurus*		*G. filamentosus*		Total fry in each tin		Total
	Alive * (Small)	Dead * (Small)	Alive * (Large)	Dead * (Large)	Alive	Dead	Alive	Dead	Alive	Dead	
1	32	nil	10	4	42	31	16	2	100	37	137
2	99	17	76	nil	4	nil	nil	nil	179	17	196
3	89	14	17	6	6	,,	1	11	83	31	114
4	115	32	63	4	4	,,	1	4	183	40	223
Total	305	63	166	14	56	31	18	17	545	125	670

* Small size, less than 1 inch; Large size, above 1 inch.

Mortality during transport has been heavier in the case of smaller mullets than in the larger specimens. In *Elops* and *Gerres* also the mortality has been very high. The physico-chemical conditions of water at the collection spot and during transport were as follows:

TABLE VIII

Serial No.	Location of sample	Time	Temp. °C.	S. ‰	Free CO_2	CO_3	HCO_3	pH	D.O. c.c./l.	% Sat.	Remarks
1	From the 'Kalvai'	8·30 A.M.	26·6	28·32	nil	3·3	15·25	8·4	2·462	41·9	
2	From the tin carrier before transport	11·45 A.M.	31·2	28·32	,,	3·6	20·44	8·3	2·111	..	
3	From the tin carrier at Chetput	4 P.M.	30·6	,,	,,	2·7	19·98	8·2	2·990	54·2	

The live specimens were then segregated into species in separate tubs in Table IX.

The volume of water in all the tubs was equal; and the salinity was also reduced by 8·96 at a time, as in Experiment IV and the fry were brought to freshwater in 3 stages in the course of 12 hours. The hydrological condi-

TABLE IX

Tub No.	Species	Size	Number	Remarks
1	*Mugil* spp.	0·5" to 0·75"	305	..
2	*Mugil* spp.	1·0" to 1·5"	166	..
3	*E. indicus*	2·0" to 2·5"	56	..
4	*G. filamentosus*	0·75" to 1·25"	18	..

tions and the reaction of the fry were noted as in the previous experiment and are tabulated below:

TABLE X

Experiment V: Tub No. 1. Small mullets—Total Period—12 hours

Serial No.	Date	Time	Before (A) or after (B) dilution	Dilution Interval	Temp. °C.	S. ‰	*Free CO_2	*CO_3	*HCO_3	pH	D.O c.c./l.	% Sat.	No. of Fry	No. died	% Mortality	Remarks
1	17-2-47	7 P.M.	A	..	26·5	28·32	nil	2·10	28·37	8·6	0·070	1·19	303	..	..	
2	,,	,,	B	..	26·4	19·59	,,	2·40	22·06	8·5	2·005	33·99		10		
3	18-2-47	1 A.M.	A	6 hrs.	23·1	,,	,,	1·05	25·32	8·3	1·126	18·07		18		
4	,,	,,	B	..	26·0	10·74	,,	1·50	25·16	8·5	3·659	61·60		..		
5	,,	7 A.M.	A	6 hrs.	28·2	,,	,,	1·20	25·11	8·1	2·111	36·82		10		
6	,,	,,	B	..	25·6	0·14	,,	2·10	23·18	8·4	3·589	62·03				
7	,,	12·20 P.M.				0·14								57		
														95	31·3	

Experiment V: Tub No. 2. Larger mullets—Total Period 12 hours

1	17-2-47	7 P.M.	A	..	26·5	28·32	nil	2·10	23·49	8·5	0·352	5·97	166	..	..	
2	,,	,,	B	..	26·6	19·59	,,	1·50	24·86	8·5	2·111	35·90		9		
3	18-2-47	1 A.M.	A	6 hrs.	22·0	,,	,,	1·05	25·93	8·3	0·926	14·24		2		
4	,,	,,	B	..	26·8	10·74	,,	1·50	25·32	8·5	4·784	81·70		..		
5	,,	7 A.M.	A	6 hrs.	28·3	,,	,,	0·75	26·84	8·0	1·055	18·45		15		
6	,,	,,	B	..	26·0	0·14	,,	1·05	25·93	8·2	3·440	58·06		8		
7	,,	12 noon														
														34	20·5	

Table X—(*Contd.*)

Experiment V: Tub No. 3. *Elops saurus*—Total Period 12 hours

Serial No.	Date	Time	Before (A) or after (B) dilution	Dilution Interval	Temp. °C.	S. °/₀₀	*Free CO_2	*CO_3	*HCO_3	pH	D.O c.c./l.	% Sat.	No. of fry	No. died	% Mortality	Remarks
1	17-2-47	7 P.M.	A	..	27·2	28·32	nil	3·60	19·52	8·7	2·814	48·34	56	..	..	
2	,,	,,	B	..	26·8	19·59	,,	2·70	21·81	8·6	3·238	55·27		5	..	
3	18-2-47	1 A.M.	A	6 hrs.	23·0	19·59	,,	,,	22·42	8·5	1·809	28·97		3		
4	,,	,,	B	..	26·4	10·74	,,	2·10	24·10	8·6	4·643	78·70		..		
5	,,	7 A.M.	A	6 hrs.	28·3	,,	,,	,,	23·18	8·2	2·990	52·25		4		
6	,,	,,	B	..	26·6	0·14	,,	1·80	24·10	8·3	3·941	68·11		..		
7	,,	12·30 P.M.												13		
														25	44	

Experiment V: Tub No. 4. *Gerres filamentosus*—Total Period 12 hours

1	17-2-47	7 P.M.	A	..	26·6	28·32	nil	2·40	19·54	8·6	1·548	26·32	18	..	..	
2	,,	,,	B	..	26·7	19·59	,,	2·40	20·44	8·6	3·377	57·53		4		
3	18-2-47	1 A.M.	A	6 hrs.	23·1	19·59	,,	2·85	20·43	8·5	2·321	37·27		2		
4	,,	,,	B	..	26·4	10·74	,,	2·70	22·88	8·6	4·504	76·33		..		
5	,,	7 A.M.	A	6 hrs.	28·4	10·74	,,	2·25	23·25	8·3	3·709	64·91		7		
6	,,	,,	B	..	28·4	0·14	,,	2·10	,,	8·4	4·222	71·93		..		
7	,,	9 A.M.												4		
														17	94	

* Results expressed in parts per 100,000.

Remarks.—Even though the duration of the experiment and the change in salinity during the different stages were common in all the experimental tubs, heavy mortality (31·3%) is recorded in the case of the smaller mullets. In the larger specimens also the mortality is high (20·5%) though relatively less than in the former. Comparing with the conditions in Experiment IV two factors are seen to be slightly variable. In the present case the salinity of water at the collection spot was higher than in the previous collection; and the final step of dilution in this case was from 10·74 to 0·14 of salinity. It is likely that these factors might have contributed to cause the heavy mortality. In the case of *E. saurus* and *G. filamentosus* the heavy mortality

(44% and 94% respectively) is only attributable to the inherent incapacity of the species to withstand the sudden hydrological changes. The very heavy mortality in *E. saurus* even during the short duration of transport is significant in this connection.

Since no actual 'Control' was kept in this experiment also the extent of the mortality due to mechanical shock and injuries that would have resulted even in pure brackish water, cannot be correctly estimated. As in the previous experiment, mortality due to rigours of acclimatisation would therefore be really much less than what is now recorded.

EXPERIMENT VI

During the first week of October 1947, the river Adyar established connection with the sea by the opening of the sand bar across its mouth. Millions of post-larval leptocephalus like specimens of *Megalops cyprinoides* and *Elops saurus* and post-larval specimens of mullets, *Gerres*, *Scatophagus*, *Sillago*, *Ambassis* and *Hemirhamphus* were then found entering the back-

TABLE XI

Stages of reduction in the salinity of water during acclimatisation of Leptocephalus-*like post-larvæ of* E. saurus *and* M. cyprinoides

Jar No.	Salinity													
	Brackish water	1st dilution			2nd dilution			3rd dilution			No. of fish	Reaction	% Mortality	Remarks
		Vol. of water c.c.	S°/₀₀	Duration (hours)	Vol. of water c.c.	S°/₀₀	Duration (hours)	Vol. of water c.c.	S°/₀₀	Duration (hours)				
1	18·54	Control		—	48	hours	..	2000	c.c. of	water	10	Normal	nil	
2	,,	2000	13·93	21·0	3500	8·00	2·0	2000	0·14	..	10	,,	,,	Third dilution to fresh-water
3	,,	2500	11·17	21·5	2250	3·67	1·5	2000	0·14	..	10	,,	,,	do
4	,,	3000	9·32	23·0	2500	1·84	1·15	2000	0·14	..	10	,,	,,	do
5	,,	3500	8·00	20·5	2000	3·93	3·0	2000	0·14	..	10	,,	,,	do
6	,,	2000	13·93	2·5	2000	0·14	..	..	..	..	10	,,	,,	Second dilution to fresh-water
7	,,	2900	3·67	4·0	2000	0·14	..	..	..	..	10	,,	,,	do
8	,,	2500	1·48	5·25	2000	0·14	..	..	..	..	10	,,	,,	do
9	,,	2000	0·14	..	..	..	..	..	..	..	10	,,	,,	Sudden transfer to fresh-water
10	,,	10,000	0·14	..	..	..	..	..	..	..	10	,,	,,	do

waters from the sea through the open bar. A series of experiments on their acclimatisation to freshwater was carried out by stepping down the salinity in different stages and duration. The details of these experiments are incorporated in Table XI.

It was found that besides *E. saurus* and *M. cyprinoides* post-larval stages of *Scatophagus argus* and *Ambassis* sp. could also be successfully transferred direct from brackish water to fresh water. It is remarkable that even direct transfer from brackish water to freshwater involving extreme fluctuations in environmental factors is manifested only in visibly mild reaction for a short duration.

Discussion

The salinity of water in the estuaries and backwaters is daily subject to wide fluctuation. It is seen that the chloride content of water at low tide in the shallow expanses at Adyar is only about half the chloride content of the incoming high tide water. It is therefore clear that the estuarine and brackish water species are being daily subjected to a certain degree of acclimatisation to conditions of changing salinity. The success of experimental acclimatisation of saltwater fish seed will therefore depend on the care with which the young fry are handled and the gradual stepping down of salinity. In the experiments reported in this paper, the fry were collected from Adyar and transported in carts for a distance of about 8 miles in the open sun, the duration being about 3 to 4 hours. In all the experiments the mortality of fry during this stage of transport was appreciable. Mechanical injury and shock during collection and transport will certainly weaken the resistance of the fry and this is bound to reflect adversely during acclimatisation. This could possibly be avoided if field facilities are provided at Adyar for carrying out the experiments so that the transport stage could be avoided.

Prolonged course of acclimatisation is bound to tell on the condition of the fry, particularly if they are not fed, since they have to cope up with the increased metabolic activity during acclimatisation, starving. Experiments have indicated that feeding during acclimatisation is beneficial to the fry.

Dilution of water and stepping down of salinity should always be by gradual steps. In our experiments a difference of 8·96 of salinity at each dilution gave encouraging results. Longer duration in each grade of water is also harmful since the increased metabolic activity will soon deplete the oxygen content of water, reduce the pH and result in accumulation of carbon dioxide, all of which are deleterious to the young fry. For post-larval mullets, 0·5 to 1·5″ long, stepping down the salinity by 5·28 at every 4-hour period would appear to give very encouraging results.

The experiments on post-larval leptocephalus like stages of *E. saurus* and *M. cyprinoides* have clearly demonstrated that at this particular stage they are capable of withstanding extremely wide and sudden fluctuations in the salinity of water. This is in sharp contrast to the reaction of the same species in the fingerlings stage. In the fingerling stage these two species are very sensitive to the strain of transport and acclimatisation and as shown in Experiment V heavy mortality results. Even after acclimatisation to freshwater *E. saurus* is appreciably susceptible to strain during transport, as is generally experienced when they are occasionally collected from the freshwater sections of the river Cooum for stocking purposes. The fact that either during transport or during the different laboratory experiments not a single leptocephalus died is proof that they are best acclimatisable at this particular stage. Similar acclimatisable stages for the other species have to be experimentally ascertained for the proper exploitation of the salt water fish seed resources and further detailed field experiments, preferably at the collection spot itself are urgently necessary.

SUMMARY

1. Laboratory and field experiments, carried out during 1945–48 on the acclimatisation of fry and early fingerlings of mullets (*Mugil cephalus*, *M. sehelii*, etc.), *Megalops cyprinoides* and *Elops saurus* (leptocephalus and later stages), *Gerres filamentosus*, *Scatophagus argus*, *Sillago sihama*, *Hemirhampus gaimardi* and *Ambassis* sp. are described.

2. An attempt has been made to elucidate the physico-chemical variables in the medium during the several stages of transition of the young fish from salt water to freshwater.

3. In the early post-larval stage, most of the above fishes possess the capacity for quick adaptation to wide and sudden fluctuations in salinity and other environmental conditions; but advanced stages (2 to 3 inches long) of atleast *Megalops* and *Elops* are found to be more susceptible to such changes, resulting in considerable mortality.

4. The knowledge that these common food fishes, at this early stage, can withstand even direct transfer from brackish water to freshwater has a bearing on the possibilities of their successful culture in freshwater. Their small size and low mortality during acclimatisation would enable transport of large numbers at relatively low cost.

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